SOIL SURVEY OF IOWA

DELAWARE COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section

Soils

Soil Survey Report No. 56

May, 1929

Ames, Iowa

IOWA AGRICULTURAL EXPERIMENT STATION

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May, 1929 Soil Survey Report No. 56

SOIL SURVEY OF IOWA

Report No. 56—DELAWARE COUNTY SOILS

By W. H. Stevenson and P. E. Brown with the assistance of Bryan Boatman, L. W. Forman, H. R. Meldrum and R. E. Bennett

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

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DELAWARE COUNTY SOILS*

By W. H. Stevenson and P. E. Brown with the assistance of Bryan Boatman, L. W. Forman, H. R. Meldrum and R. E. Bennett

Delaware County is located in northeastern Iowa, in the second tier of counties west of the Mississippi River and in the third tier south of the Minnesota state line. It is partly in the Iowan drift soil area and partly in the Mississippi loess area and hence the soils are partly of glacial and partly of loessial origin.

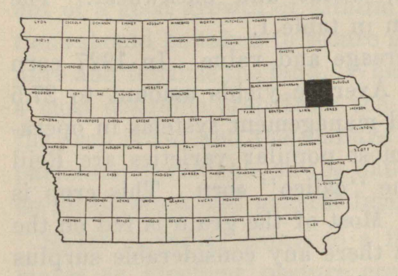


Fig. 1. Map showing the location of Delaware County.

The total area of Delaware County is 571 square miles or 365,440 acres. Of this area 349,009 acres or 95.5 percent are in farmland. The total number of farms is 2,191, and the average size of the farms is 159 acres. Owners operate 49.3 percent of the total farm land and renters 50.7 percent. The following figures taken from the Iowa Yearbook of Agriculture for 1927 show the utilization of the farm land of the county.

Acreage in general farm crops	211,317
Acreage in farm buildings, feed lots, and public highways	15,361
Acreage in pasture	117,844
Acreage in waste land not utilized for any purpose	3,212
Acreage in farm woodlots used for timber only	2,289
Acreage in crop land lying idle	1,895
Acreage in crops not otherwise listed	175

THE TYPE OF AGRICULTURE IN DELAWARE COUNTY

The type of agriculture most commonly followed in Delaware County at the present time consists of a system of general farming, including the raising and feeding of hogs and cattle and the production of such general crops as corn, oats, wheat and hay. The income on such farms comes from the sale of livestock and of surplus grain crops. Many farms are operated on a strictly livestock basis, and the crops are all utilized for feeding purposes on the farms. Dairy farming is also practiced rather extensively, and on many farms which are not operated on a dairy basis exclusively, considerable income is provided from dairy products. In general the farm income thruout the county comes mainly from the sale of hogs; this is followed by the income from dairy products and beef cattle and finally by the income from the sale of general farm crops. On individual farms the sale of special crops or some other particular livestock industry than those mentioned may bring in some income.

The acreage in waste land is considerable and much of this land might be reclaimed and made productive by the adoption of the proper methods of soil treatment. It is impossible to give any general recommendations for the treatment of such land, as the causes of unproductiveness are so varied that different methods of handling the soils must be practiced in different cases. In a later

*See Soil Survey of Delaware County, Iowa, by Clarence Lounsbury of the U. S. Department of Agriculture and Bryan Boatman of the Iowa Agricultural Experiment Station. Field Operations of the Bureau of Soils, 1922.

section of this report suggestions will be offered for the management of land in the different soil types where at present crop yields are poor or at all unsatisfactory. In special cases, where the conditions are more or less abnormal, advice regarding soil treatments will be furnished by the Soils Section of the Iowa Agricultural Experiment Station upon request.

THE CROPS GROWN IN DELAWARE COUNTY

The general farm crops grown in Delaware County, in the order of their importance, are corn, oats, hay (clover and timothy mixed, clover alone and timothy alone), barley, potatoes, alfalfa, rye, wheat and buckwheat. The average yield and value of these crops are given in table I.

Corn is the most important crop, both in acreage and value. In 1927 corn occupied 25.6 percent of the total farmland. Average yields amount to 27.5 bushels per acre. On the better soils, with good management systems in operation, the yields are very much greater. The most popular varieties are Reid Yellow Dent, Silver King, Silvermine and some "calico" corn. This crop is grown on practically all soils and on all farms. Most of the grain is fed on the farms and only in a limited number of cases is there any considerable surplus for sale.

The second crop in acreage and value is oats. This crop is grown on 17.4 percent of the total farm land, and yields average 26.0 bushels per acre. Very much larger yields are obtained on the richer soils and on areas where good soil management practices are followed. The varieties grown are chiefly Kherson, Iowa 103, Iowa 105 and Iowar. The entire crop is utilized for feed on the farms.

TABLE I. AVERAGE YIELD AND VALUE OF PRINCIPAL CROPS GROWN IN DELAWARE 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 crops
Corn	89,464	25.6	27.5	2,460,260	$0.69	$1,697,579
Oats	60,914	17.4	26.0	1,583,866	0.42	665,224
Winter wheat	16	0.01	23.4	374	1.17	438
Spring wheat	250	0.07	16.7	4,171	1.15	4,797
Barley	4,034	1.1	25.2	101,705	0.66	67,125
Rye	861	0.24	10.7	9,182	0.86	7,897
Clover hay†	3,436	0.98	2.13	7,319	12.50	91,488
Timothy hay	7,379	2.1	1.13	8,338	10.50	87,549
Clover and timothy hay (mixed)	34,444	9.9	1.41	48,566	11.77	571,622
All other tame hay	687	0.19	2.74	1,882	11.77	22,151
Alfalfa	381	0.11	3.01	1,147	16.00	18,352
Wild hay	3,992	1.1	1.06	4,232	10.00	42,320
Soybeans grown with other crops	1,586	0.45	------	--------	------	----------
Soybeans grown alone and for seed	269	0.07	------	--------	------	----------
Potatoes	608	0.17	51	31,008	1.00	31,008
Flax seed	6	0.01	10	60	1.95	117
Buckwheat	141	0.04	13.7	1,935	0.85	1,645
Timothy seed	1,545	0.44	5.6	8,626	1.65	14,233
Clover seed†	1,260	0.36	.82	1,038	16.10	16,712
Sweet clover‡	119	0.03	------	--------	------	----------

*Iowa Yearbook of Agriculture, 1927.
†Sweet clover not included.
‡All varieties for all purposes.

Hay is produced very extensively. In 1927, clover and timothy mixed was grown on 9.9 percent of the total farm land, clover alone, on 0.98 percent and timothy alone on 2.1 percent of the farm land. In addition wild hay was produced on 1.1 percent, alfalfa on 0.11 percent and all other tame hay on 0.19 percent, of the farm land. The value of all the hay produced is considerable. The yields of clover and timothy amount to 1.41 tons per acre; of clover alone, to 2.13 tons; and of timothy alone, to 1.13 tons. Wild hay yields 1.06 tons and alfalfa 3.01 tons per acre. The latter crop is proving a most profitable one where it is successfully grown. Lime must be applied to acid soils to permit of a good growth of alfalfa. Alfalfa seed should be inoculated, and precautions should be taken to secure good seed, to prepare a good seedbed and to manure and fertilize the land. When these items are all taken care of, alfalfa proves a most desirable crop from the feeding and soil fertility standpoints, provided the crop is fed and the manure produced is returned to the land. This crop is particularly valuable on the dairy farm but it is also a distinctly profitable crop on all livestock and general farms.

Sweet clover is grown to a limited extent, chiefly for pasture purposes. It makes an excellent pasture crop and is valuable for increasing soil fertility. Some sweet clover is grown for seed. Some red clover and some timothy are also grown for seed, but no large areas of these crops are used in this way. There is a small acreage in soybeans.

The entire hay crop is utilized for home consumption. Potatoes are grown on practically all farms to supply the home demand and for sale on the local markets. Average yields amount to 51 bushels per acre.

Barley is grown on 1.1 percent of the farm land, and yields average 25.2 bushels per acre. It is all used for feed on the farms. Rye is produced to a limited extent, and yields of 10.7 bushels per acre are secured. There is a small acreage in buckwheat, and wheat is grown only on a small acreage. The Turkey is the variety of wheat usually grown. Wheat is largely a cash crop.

Some sweet corn is grown, which is sold to the canning company at Dyersville in Dubuque County. Some sorghum is grown for syrup, and some flax seed is produced. The production of fruits and vegetables is limited to the needs of individual farms. There is no surplus produced, and these industries are not developed to a commercial extent.

THE LIVESTOCK INDUSTRY IN DELAWARE COUNTY

The livestock industries of the county include the raising and feeding of hogs and cattle, dairying, some raising of sheep and some breeding of horses. The following figures taken from the Iowa Monthly Crop Report for July 1, 1928, giving the January 1, 1928, estimates of the Bureau of Agricultural Economics in cooperation with the Iowa State Department of Agriculture show the extent of the livestock industries:

Horses	11,200
Mules	620
Cattle (all)	41,500
Hogs	81,500
Sheep	5,900

The principal source of farm income in many cases is from the sale of hogs. The raising and feeding of hogs is undoubtedly the chief livestock industry.

The average farmer sells 30 to 50 fattened hogs annually and many sell as many as 75 or 100 in addition to supplying the home needs. The leading breeds are the Poland China, Duroc-Jersey and Chester White, with some Berkshire and Hampshire. On January 1, 1928, there were 81,500 hogs on the farms in the county.

The raising and feeding of beef cattle is an important industry. The favorite breed is the Shorthorn, altho there are some Herefords and a few Aberdeen Angus. A considerable portion of the cattle are shipped in, fed and later sold on the markets.

The dairy industry has been quite extensively developed in recent years. The favorite dairy breeds are the Holstein and the Guernsey, with some milking Shorthorn. Generally the cream is separated on the farms and is sold to the creameries in the adjacent towns. One creamery receives whole milk and a number of the dairies supply whole milk to their customers. The income from the dairy products is considerable.

Sheep raising is practiced on some of the rougher lands. Most of the sheep are grade Shropshires. The industry is not extensive, but on some farms the sale of the animals and of the wool produced provides considerable income.

Many farmers raise one or two colts annually to keep up their work stock. A few mules are raised also. The Percheron and Belgian horses are most common. The horse industry is not developed on a commercial basis, however.

The income from poultry and poultry products is increasing on many farms as more attention is being paid to the industry. The most popular breeds are the Plymouth Rock and Leghorn. The total value of the poultry, including chickens, ducks, geese and turkeys and poultry products, is considerable.

The value of the land in Delaware County is extremely variable, depending upon the location with reference to towns and railway facilities, the improvements on the farms, the topographic conditions and the natural soil conditions. The better areas are worth around $250 per acre, while the poorer land will sell for $50 to $60 per acre.

THE FERTILITY CONDITION IN DELAWARE COUNTY SOILS

In general the average yields of farm crops in Delaware County are fairly satisfactory, but in many cases much larger crops might be secured thru the adoption of proper methods of treatment. Where the land is not adequately drained, the installation of tile should be the first soil treatment. Land which is too wet will not produce properly and, while tiling may prove somewhat expensive, the value of the increased crop yields will make the outlay worth while. On the Clyde silt loam on the drift uplands of the county, there is particular need for drainage. There are also certain areas in others of the upland types where drainage is inadequate. On the terraces, the Bremer soils are poorly drained and the Wabash types on the bottoms are especially in need of drainage. In all such cases the installation of an adequate drainage system is essential before any other soil treatments are employed to benefit crops.

All of the soils in the county are acid in reaction and, therefore, in need of lime. Satisfactory yields of general farm crops and particularly of legumes cannot be secured on acid soils. It is very desirable, therefore, that all the soils in the county be tested for lime needs and that the proper application of lime be made if the most satisfactory crop growth is to be secured. Large increases in such crops as alfalfa and sweet clover are obtained by the use of lime. The benefits of additions of lime have been definitely shown on these crops and have also appeared in many cases on other general farm crops. In the upbuilding and maintenance of the fertility of the soils of this county the application of lime, as needed, may be considered a basic and fundamental treatment.

Many of the soil types are not very well supplied with organic matter and nitrogen, and additions of fertilizing materials supplying these constituents are very desirable. All the soils, however, are in need of such fertilizing materials, applied at regular intervals, if the content of organic matter and nitrogen is to be kept up. The liberal application of farm manure to the soils of this county is strongly recommended and large increases in the yields of general farm crops will follow its use. All crop residues should be thoroly utilized on the farm to aid in maintaining the supply of organic matter and nitrogen. Where insufficient farm manure is produced to permit of a regular supply to all the land on the farm, the turning under of leguminous crops as green manures is a very desirable practice. When well inoculated, legumes will take a large part of their nitrogen from the atmosphere and when turned under will increase the nitrogen content of the soil. Legumes also add a large amount of valuable organic matter. On the light colored, coarse-textured sandy soils, it is particularly important that organic matter be supplied, and the use of farm manure, crops residues and leguminous green manures is of special value. Even on the heavier types of soils and those which are darker in color, the regular use of these natural fertilizing materials is very desirable to stimulate the production of available plant food and to permit of the maintenance of the proper amount of organic matter and nitrogen in the land.

Analyses of the soils of Delaware County show that the phosphorus content is rather low. It is evident, therefore, that the addition of a phosphate fertilizer will be necessary in the very near future. Some evidence has been secured, however, to indicate that the application of a phosphate fertilizer may be of large value in many cases on these soils at the present time. Either rock phosphate or superphosphate may be employed and economic returns secured from the application. Farmers are urged to test both phosphate fertilizers under their particular conditions and thus determine whether or not a phosphorus fertilizer will prove profitable for use and which phosphorus carrier may be used most economically. Complete commercial fertilizers may also be tested in comparison with the phosphates. Their general use cannot be recommended at the present time but if tests carried out under field conditions indicate their value, there is no possible objection to their use. It is merely a question of the economic returns secured from the application.

Erosion occurs to a considerable extent in Delaware County, and a number of the soil types are rather seriously injured by this destructive action. In many cases gullies are formed and naturally fertile areas of land are made unproductive. Sheet washing often occurs and leads to the removal of much or all of the more fertile surface soil, leaving the underlying subsoil exposed. Wherever these injurious effects of erosion are evident, some method should be employed to prevent or control the action. From among the methods suggested later in this report, some one may be chosen which will prove satisfactory under any soil conditions.

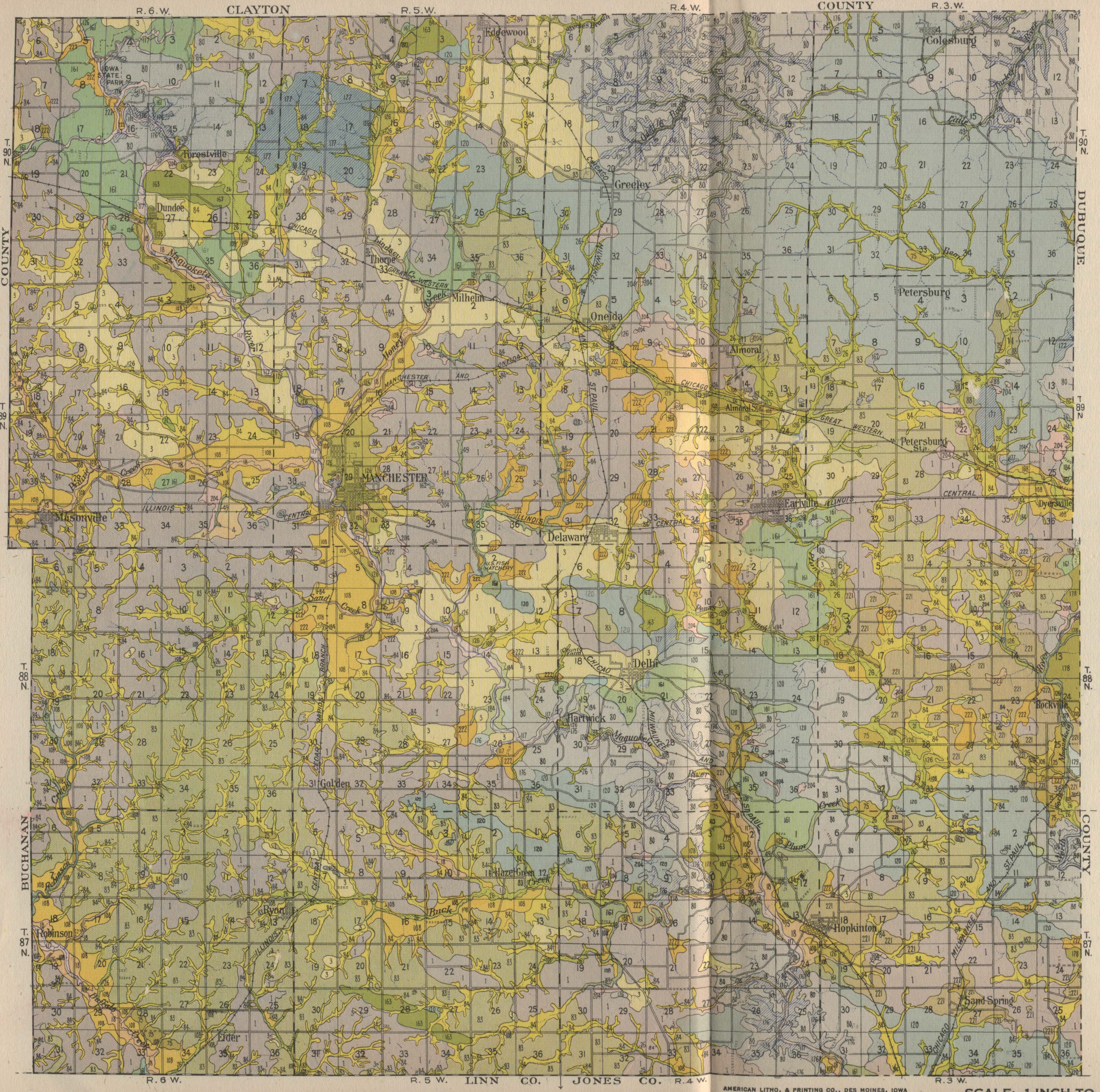
THE GEOLOGY OF DELAWARE COUNTY

The native bedrock material underlying the soils of Delaware County consists chiefly of shales and limestone. Occasional outcroppings of the underlying rocks occur in narrow ledges, but these areas are relatively unimportant from the agricultural standpoint. Only one soil type, the Gasconade loam, is derived from the underlying limestone rock. It covers only a small area, occurring mainly in the eastern part along slopes leading to the larger streams and in isolated, elevated areas. The soils of the Dodgeville series are also affected by the underlying lime rock. The surface covering of these soils is of loessial origin but is very shallow, and the underlying rock appears in the three-foot section. In the case of the Gasconade loam, however, the surface soil is formed from the weathering of the underlying rock and this type is classified as a residual soil.

Except for the areas which have been mentioned, the bedrock material in Delaware County has been so completely covered by deposits of glacial drift and still later by loessial deposits that there is no effect on the soil conditions. At least three times during the glacial age, great ice sheets swept over the county and upon their retreat left behind thick deposits of glacial till or drift. The earliest of these glaciations, the pre-Kansan, consisted of a greenish-blue or grayish-blue clay, filled with gravel and boulders. None of the soils developed in the county have been formed from this pre-Kansan deposit and it has, therefore, no agricultural significance.

A second glacier, the Kansan, swept over the entire county and left behind a rather extensive drift deposit in all parts of the area. The deposit varies in depth from a few feet to a hundred feet. This drift material consists chiefly of a blue clay, containing numerous boulders of varying size. When weathered, the surface material has been oxidized to a reddish-brown color and is underlaid by a yellowish boulder clay, grading into the unoxidized blue clay of the original drift. None of the soil types have been derived entirely from this Kansan till as it was covered at later periods by other deposits. In some instances, however, the erosion which has taken place since the later deposits were made, has led to the exposure of this underlying material or at least to its appearance within the three-foot section. Thus the soils of the Shelby series and of the Lindley series are derived in part from the Kansan till, the surface covering of these soils having been formed from the later deposits. Associated with the old drift deposits there are occasional beds of gravel which are known as Buchanan gravels. Some of these deposits have been carried over the upland, and the material has an effect on the subsoil condition of some of the soil types, particularly the Thurston sandy loam.

The third glaciation, known as the Iowan, covered practically all of the southwestern part of the county and left a deposit varying in thickness from 10 to 20 feet. It consists of a yellow clay, containing numerous boulders, sand and coarse gravel. The soils of the Carrington, Clyde and Thurston series are derived from this Iowan drift material, and the surface covering of the Lindley



AMERICAN LITHO. & PRINTING CO., DES MOINES, IOWA

SCALE: 1 INCH TO 2½ MILES

SOIL MAP OF DELAWARE COUNTY IOWA

Thomas D. Rice, Inspector, Northern Division. Soils Surveyed by Clarence Lounsbury of the U. S. Department of Agriculture and Bryan Boatman of the Iowa Agriculture Experiment Station.

U. S. DEPARTMENT OF AGRICULTURE, BUREAU OF SOILS
Henry G. Knight, Chief. A. G. McCALL, in Charge Soil Investigations
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IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtiss, Director W. H. Stevenson, in charge Soil Survey
P. E. Brown, Associate in Charge

LEGEND

Drift Soils

- 1 Carrington loam
- 83 Carrington silt loam
- 84 Clyde silt loam
- 3 Carrington sandy loam
- 161 Lindley sandy loam
- 221 Shelby sandy loam
- 4 Carrington fine sandy loam
- 162 Thurston sandy loam

Loess Soils

- 176 Clinton silt loam (steep phase)
- 120 Tama silt loam
- 80 Clinton silt loam
- 222 Dodgeville sandy loam
- 163 Fayette silt loam
- 204 Dodgeville silt loam
- 178 Clinton very fine sandy loam
- 177 Tama silt loam (light colored phase)

Terrace Soils

- 108 O'Neill loam
- 126 O'Neill sandy loam
- 75 Waukesha silt loam
- 88 Bremer silt loam
- 179 Judson loamy sand

Swamp and Bottomland Soils

- 26 Wabash silt loam
- 18 Cass loam
- 117 Genesee fine sandy loam
- 49 Wabash loam
- 21 Peat

Residual Soil

- 184 Gasconade loam

and Shelby soils is undoubtedly of Iowan origin, altho the subsoil has been formed from the underlying Kansan till.

At a much later date in geological history, when climatic conditions were very different than those occurring at present, there was laid down over the surface of the county a deposit of finely divided silty material known as loess. The deposition was undoubtedly made by the winds. In its original unweathered condition, loess consists of a yellowish, fine grained silty material. It varies widely in thickness, being somewhat deeper in the eastern part of the county and thinning out towards the drift sections. The weathering of the loessial material and the accumulation of plant residues have brought about a darkening in the color of the original material, and the erosion which has occurred extensively in some sections has caused considerable variation in the thickness of the loessial covering. The soil types of loessial origin include the Tama, the Clinton, the Dodgeville and the Fayette. The Tama soils were formed under prairie conditions and are darker in color than the other loessial types. The Fayette and Clinton soils were developed in timbered sections. They are much lighter in color and contain less organic matter. The Dodgeville types are developed on areas where the loessial covering has been largely removed, and the native limestone rock appears within the three-foot section.

Terraces or second bottomlands have been developed to some extent and are derived largely from the glacial and loessial material washed down from the adjacent uplands. They have been modified also to a considerable extent by the beds of gravel laid down in the glacial age. The higher terraces are classified in the O'Neill and Waukesha series. The Judson soils are largely colluvial and are rather recent in formation, having been modified considerably by the wash from the adjacent upland. The Bremer soils are developed on more recent terraces. The bottomland soils are formed from loessial and glacial materials washed down from the upland and are subject to overflow; they are, therefore, being modified more or less irregularly in their various characteristics. The bottomland soils are classified in the Wabash, Cass and Genesee series and they are found in relatively narrow areas along the various streams and creeks.

PHYSIOGRAPHY AND DRAINAGE

There are two main topographical divisions of Delaware County, the first occupying about two-thirds of the area, generally in the southwestern part, is characteristic of the Iowan glaciation. It consists of a broad plain marked by gently rounded eminences and broad swales which extend, finger-like, thruout the uplands and have no well developed drainage channels. Depressions at the heads of the sloughs mark the beginnings of the drainage courses which lead to the larger streams. This topographic situation is best developed southwest of the Maquoketa River in Adams, Hazel, Green Prairie, Milo and Coffins Grove townships. Northeast of the river the drift plain is represented in Delaware, Honey Creek, Oneida and Bremen Townships.

Along the edges of the Iowan glaciation are low dome-like, rocky knobs projecting above the drift indicating older topographic features. In other areas are irregular rock masses and weathered crags which have apparently not been affected by the glaciation. The latter are evident in the southwest quarter of

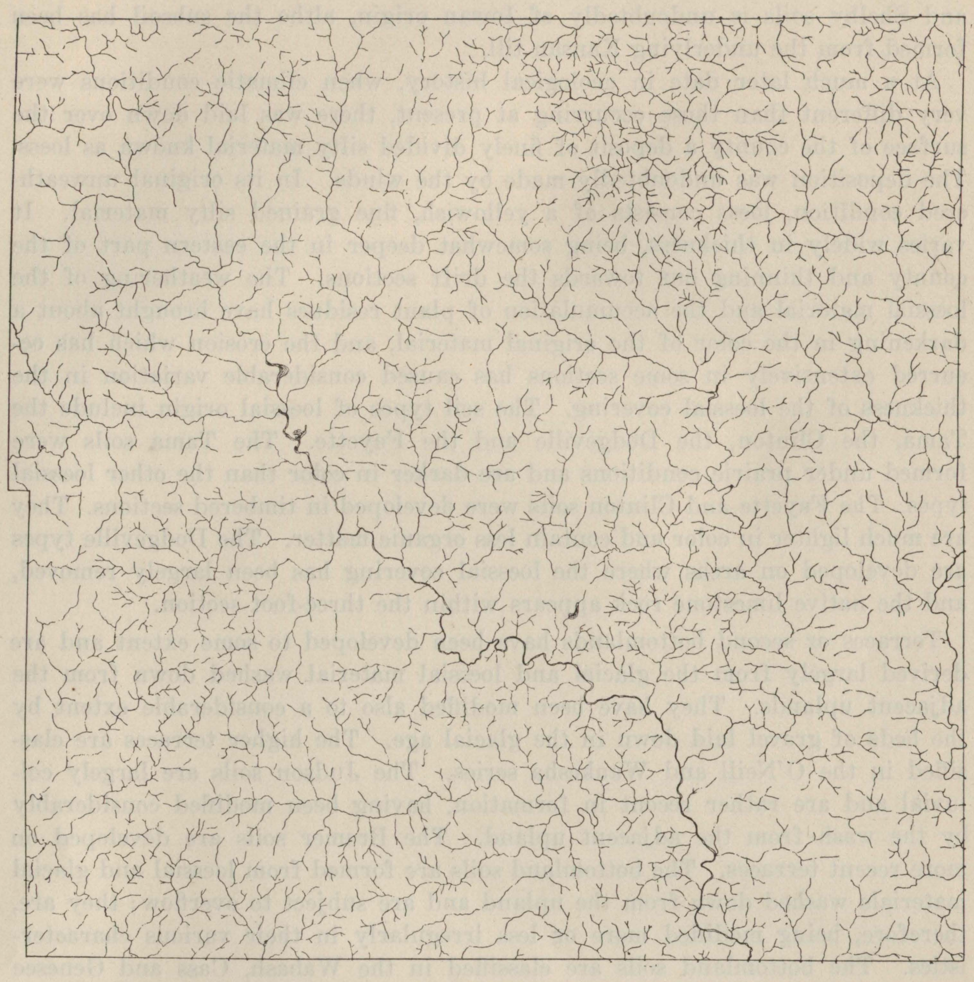

Fig. 2. Map showing the natural drainage system of Delaware County.

Section 2 and in the southeast quarter of Section 3 of Delhi Township, and the former appear in the northwest quarter of the southwest quarter of Section 2 of Delaware Township. Along the edge of the Iowan drift area are also elongated hills or ridges, sometimes isolated and sometimes connected and extending for miles. These ridges are known as "pahas." Here the underlying material is rock or Kansan drift covered by a thin layer of loess. This formation occurs in Sections 3, 4 and 12 of Honey Creek Township and in Sections 6, 7 and 18 of Elk Township. In places sand ridges or dune-like formations occur in the Iowan drift area. There is a typical sand ridge in the southeast corner of Section 1 of Delaware Township and another about one mile northwest of Earlville.

The second main topographic division occurs northeast of a line running from the northwestern corner of Elk Township in a southeasterly direction to a point near the southwestern corner of Bremen Township. This is the loessial area. Here the surface is characterized by ridges and narrow valleys but there are no sloughs. The drainage courses are well defined. The earlier topographic

features of the Kansan drift plain have modified the surface conditions to a considerable extent, but the loess was laid down rather evenly over the surface of the land and subsequent erosion of the loessial material has modified the topographic features to some extent, accentuating rather than reducing the previous topographic features. Adjacent to the drift area there are loessial hills which rise above the more gently undulating typical loessial topography to the east. Here there are V-shaped valleys, sharply rounded hills and evidence of considerable erosion. The valleys of Elk Creek and Little Turkey River which flow thru this region are cut 200 to 280 feet deep thru the loess and drift down to the underlying areas of native bedrock.

There are two areas in the Iowan drift region which apparently were not invaded by the Iowan glacier. One occurs in the central part of Richland Township and the other covers three-fourths of Delhi Township and parts of Milo, North Fork, South Fork and Union townships. Here the land is somewhat higher than that of the typical Iowan drift plain, and the valleys are steeper. There are deep deposits of loess and rounded hills with steep slopes and sharp valleys. Steep rocky cliffs, isolated towers and other features indicate the absence of both drift and loess deposits.

The terraces which are developed along the main streams rise from 10 to 50 feet above the adjacent streams. Most of them gradually grade into the uplands. Narrow bands of first bottomlands occur along the streams and have little or no topographic features.

The drainage of the county is brought about chiefly by the Maquoketa River and its tributaries. The natural drainage system is indicated in the accompanying drainage map. It is apparent that the drainage of the loessial area is adequate, but there are many areas in the drift plain where drainage conditions need to be somewhat improved if crop yields are to be most satisfactory.

West of the Maquoketa River the tributaries are mostly small streams which rise in the sloughs of the Iowan drift plain. The most important is Prairie Creek which rises in Buchanan County and flows in a shallow channel to join the river a mile above Manchester. Buck Creek with its branches drains the prairie lands of Hazel Green Township and parts of Milo and Adams Townships. From the east, Honey Creek and its tributary, Lindsay Creek, drain most of Honey Creek Township and the northern part of Delaware Township. Plum Creek carries the drainage from northern Oneida, Bremen and southwestern Elk Townships. The northern parts of Elk and Colony Townships are drained by Elk River and Little Turkey River. Buffalo Creek carries the drainage from the southwestern part of the county. The North Fork Maquoketa River near the eastern county boundary drains North Fork and South Fork Townships.

While much of the land in Delaware County is adequately drained, some areas can be materially improved thru the installation of tile. In the Iowan drift plains are numerous areas of the Clyde silt loam which are in need of drainage and other areas in the drift uplands will respond to drainage.

THE SOILS OF DELAWARE COUNTY

The soils of Delaware County are grouped into five classes, according to their origin and location—drift soils, loess soils, terrace soils, swamp and bottomland soils, and residual soils. Drift soils are formed from material carried by glaciers and left behind on the surface of the land when the glaciers retreated. They are variable in composition and contain pebbles and boulders. Loess soils are fine dust-like deposits made by the wind at a time when climatic conditions were quite different than at present. Terrace soils are old bottomlands which have been raised above overflow by a deepening of the river channel or by a decrease in the volume of the streams which deposited them. Swamp and bottomland soils occur in low, poorly drained areas along streams and subject to more or less frequent overflow. Residual soils are those which are formed from the underlying rock material and which remain resting upon it. The extent and occurrence of these groups of soils in Delaware County are shown in table II.

The largest portion of the county is covered by drift soils, 52.8 percent of the total area being in drift uplands. The loessial soils are second in area, covering 29.7 percent of the total area. Terrace soils are much less extensive and cover 5.7 percent of the county. Swamp and bottomland soils are small in total area, covering 6.1 percent of the area. There is one residual soil and it is of limited extent, covering only 0.3 percent of the total area.

There are 24 soil types in the county and those with the light colored phase of the Tama silt loam, the steep phase of the Clinton silt loam and the area of peat make a total of 27 soil areas. Each type is distinguished on the basis of certain definite characteristics which are discussed later in the appendix to this report. The areas of the different soil types in the county are shown in table III.

The Carrington loam is the most extensively developed soil type, covering 22.9 percent of the total area. It is the largest drift soil. The Carrington silt loam is the second largest drift soil and the third most extensively developed type. It covers 12.4 percent of the county. The Clyde silt loam is the third largest drift soil and the fifth largest type, covering 9.6 percent of the total area. The Carrington sandy loam is the fourth drift type in area and the sixth type in extent, covering 7.7 percent of the total area. The Lindley sandy loam is much smaller in extent, covering 3.2 percent of the county. The Shelby sandy loam is still smaller in area, covering 2.1 percent of the area. The Carrington fine sandy loam and Thurston sandy loam are both minor in area, covering 0.2 and 0.1 percent of the area, respectively.

The Tama silt loam is the largest loess type. Together with the light colored phase, which is very limited in extent, it covers 14.9 percent of the total area, being the second largest type. The Clinton silt loam, the second largest loess soil, together with the steep phase, which is much smaller in area, covers 11.9 percent of the county. It is the fourth largest type. The Dodgeville sandy loam is much smaller in area, covering only 1.5 percent of the total area. The Fayette silt loam, the Dodgeville silt loam and the Clinton very fine sandy loam are all minor in extent, covering less than 1 percent of the county. The O'Neill loam, the most extensively developed terrace type, covers 3.4 percent of the area. The O'Neill sandy loam is second in area, covering 1.4 percent of the county. The other terrace types, the Waukesha silt loam, the Bremer silt loam, and the Judson loamy sand, are minor in area, each covering less than 1 percent of the county.

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

Soil Group	Acres	Percent of total area of county
Drift soils	212,864	58.2
Loess soils	108,992	29.7
Terrace soils	20,544	5.7
Swamp and bottomland soils	21,952	6.1
Residual soils	1,088	0.3
Total	365,440	----

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN DELAWARE COUNTY

Soil No.	Soil Type	Acres	Percent of total area of county
	DRIFT SOILS		
1	Carrington loam	83,904	22.9
83	Carrington silt loam	45,440	12.4
84	Clyde silt loam	35,008	9.6
3	Carrington sandy loam	28,224	7.7
161	Lindley sandy loam	11,584	3.2
221	Shelby sandy loam	7,744	2.1
4	Carrington fine sandy loam	576	0.2
162	Thurston sandy loam	384	0.1
	LOESS SOILS		
120	Tama silt loam	50,688	----
177	Tama silt loam (light colored phase)	3,776	14.9
80	Clinton silt loam	33,152	----
176	Clinton silt loam (steep phase)	10,368	11.9
222	Dodgeville sandy loam	5,632	1.5
163	Fayette silt loam	2,368	0.6
204	Dodgeville silt loam	1,792	0.5
178	Clinton very fine sandy loam	1,216	0.3
	TERRACE SOILS		
108	O'Neill loam	12,544	3.4
126	O'Neill sandy loam	4,928	1.4
75	Waukesha silt loam	2,240	0.6
88	Bremer silt loam	704	0.2
179	Judson loamy sand	128	0.1
	SWAMP AND BOTTOMLAND SOILS		
26	Wabash silt loam	12,224	3.3
18	Cass loam	4,032	1.1
117	Genesee fine sandy loam	2,816	0.8
49	Wabash loam	2,752	0.8
21	Peat	128	0.1
	RESIDUAL SOILS		
184	Gasconade loam	1,088	0.3
	Total	365,440	----

On the bottomlands, the Wabash silt loam is the largest type, covering 3.3 percent of the county. The Cass loam covers 1.1 percent of the total area. The Genesee fine sandy loam, the Wabash loam and peat are all minor in extent, covering less than 1 percent of the county. The one residual soil, the Gasconade loam, is very minor in area, covering only 0.3 percent of the county.

There is some relation between the development of the various types and the topographic features of the upland. The Carrington soils have developed on a more gently undulating to rolling topography, while the Clyde soils occur in level to depressed topographic positions. The Shelby, Lindley and Thurston soils are generally rougher and have more striking topographic features. The Tama soils are gently rolling to undulating, while the Clinton and Fayette types are more strongly rolling to broken in topography. The Dodgeville soils show no striking topographic features. The terrace and bottomland types are usually somewhat level in topography. On the higher terraces there are some topographic variations and in the case of the Waukesha and Judson soils the topography is gently rolling. On the bottomlands the topographic features are generally lacking. The Gasconade loam, the residual soil, occurs on slopes and has, therefore, a rough topography.

The Fertility in Delaware County Soils

Samples were taken for analyses from each of the soil types in Delaware County, except the Carrington fine sandy loam, the steep phase of the Clinton silt loam, the Genesee fine sandy loam, the Gasconade loam and the peat. These soils were not analyzed because of their very limited occurrence and their unimportance agriculturally and in the case of peat, because of the great variance in the character of the material making up the soil. The more extensive soil types were sampled in triplicate, but only one sample was taken in the case of the minor types. All samplings were made with the greatest care that the results should be representative of the particular soil types and to avoid variations due to abnormal soil conditions or previous treatments. The samples were secured 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 sub-surface soil and the subsoil, respectively.

Analyses were made for total phosphorus, total nitrogen, total organic carbon, total inorganic carbon and limestone requirement. The official methods were employed in the nitrogen, phosphorus and carbon determinations and the Truog qualitative test was followed for the determination of the limestone requirements. The figures given in the tables are the averages of duplicate determinations of all samples of each type and they represent, therefore, the averages of two or six determinations.

THE SURFACE SOILS

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

There is considerable variation in the phosphorus content of the various soils in the county, the amount present ranging from 484 pounds per acre in the Lindley sandy loam up to 2,195 pounds per acre in the Cass loam. There is little evidence of any relationship between the phosphorus content of the soils and the various soil groups except that the average of the bottomland types is somewhat higher than that of the upland and terrace soils. This might be expected, inasmuch as there has been less crop growth on the bottomlands and hence a small removal of the element from the soils. The variations within groups, however, are much more striking than those between groups.

There is some evidence of a relationship between the soil series and the phosphorus content of the various types. Thus, on the drift uplands, the Clyde silt loam is richer in phosphorus than any of the other types. The Carrington soils are second and the Lindley, Shelby, and Thurston types are the lowest in this constituent. On the loessial uplands the Tama soils are the highest in phosphorus, the Clinton and Fayette types are second and the Dodgeville soils are the lowest. On the terraces the Bremer and Waukesha types are the highest while the Judson and O'Neill soils are lower. On the bottomlands the Cass loam is somewhat higher than the Wabash types. This is contrary to the usual results and is probably due to some abnormality in the particular sample analyzed.

TABLE IV. PLANT FOOD IN DELAWARE COUNTY, IOWA, SOILS
Pounds per acre of 2 million pounds of surface soil (0-6⅔")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	1,098	4,120	43,649	------	7,000
83	Carrington silt loam	1,212	5,490	57,776	------	6,500
84	Clyde silt loam	1,481	7,820	86,986	------	1,000
3	Carrington sandy loam	660	1,560	16,884	------	5,000
161	Lindley sandy loam	484	640	5,725	------	2,000
221	Shelby sandy loam	565	1,180	7,145	------	4,000
162	Thurston sandy loam	781	2,380	26,329	------	5,000
	LOESS SOILS					
120	Tama silt loam	902	3,440	32,612	------	8,000
177	Tama silt loam (light colored phase)	737	3,600	32,230	------	4,000
80	Clinton silt loam	821	2,240	26,329	------	4,000
222	Dodgeville sandy loam	633	1,700	23,436	------	5,000
163	Fayette silt loam	754	2,040	24,960	------	4,000
204	Dodgeville silt loam	821	4,520	49,674	------	4,000
178	Clinton very fine sandy loam	809	2,060	21,635	------	2,000
	TERRACE SOILS					
108	O'Neill loam	740	2,040	25,622	------	7,000
126	O'Neill sandy loam	700	1,720	17,428	------	4,000
75	Waukesha silt loam	1,185	3,200	38,060	------	5,000
88	Bremer silt loam	1,602	6,060	67,572	------	6,000
179	Judson loamy sand	619	840	8,617	------	4,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,414	3,280	44,178	------	------
18	Cass loam	2,195	7,800	75,641	------	5,000
49	Wabash loam	1,535	8,380	86,333	------	4,000

In general it is apparent that there is some relationship between those characteristics which serve to determine the soil series and the phosphorus content. The color of the soil, the topographic position and the characteristics of the subsoil are all important. Soils which are dark in color, level to flat or depressed in topography, and possessing heavier subsoils, are generally better supplied with phosphorus than are light colored types or those which occur on more rolling to steep topographic positions or have sandy or gravelly subsoils.

The texture of the soil is also of considerable importance in relation to the phosphorus content. Some comparisons along this line may be made. On the drift uplands the Carrington silt loam is richer than the Carrington loam, while the sandy loam is much lower than the loam in phosphorus. On the loessial uplands the Tama silt loam is higher than the light colored phase, as would be expected, and the Clinton silt loam is better supplied than the Clinton very fine sandy loam. There is no difference between the Dodgeville sandy loam and the Dodgeville silt loam. On the terraces the O'Neill loam is a little better supplied with phosphorus than the O'Neill sandy loam, but the difference is not great. On the bottomlands there is little difference between the Wabash silt loam and the Wabash loam. In general, however, the results bear out previous observations in showing that fine textured types are better supplied with plant food constituents than are coarse textured soils. Silt loams are usually higher in phosphorus than are loams, loams are better supplied than sandy loams and sandy loams are richer than sands or fine sands.

It is evident from these analyses that there is no large content of phosphorus in any of the soils of Delaware County. The amount present is so low that it seems certain that there will be an insufficient production of the element in an available form to keep crops supplied. Certainly some phosphorus fertilizer will be needed on these soils very soon. It seems probable, however, from the greenhouse and field experiments which have been carried out on some of the major soils in this county, that a phosphate fertilizer would be of large value on these soils at the present time. Tests of rock phosphate and superphosphate are strongly recommended.

There is a wide range in the nitrogen content of the soils, the amount present varying from 640 pounds per acre in the Lindley sandy loam up to 8,380 pounds per acre in the Wabash loam. These are the same types which showed the lowest and highest amounts of phosphorus respectively. As in the case of phosphorus, there is no evidence of a relationship between the nitrogen content of the soils and the various groups, altho the bottomland types on the average are a little better supplied than the upland soils. Again this might be expected from the lower crop growth taken from the bottomland types and hence the smaller removal of the element.

Some relationships are apparent between the nitrogen content of the soils and the various series. Thus, on the drift uplands the Clyde silt loam is the richest in nitrogen, the Carrington soils are second, the Thurston sandy loam is third and the Lindley and Shelby types are the lowest in this constituent. On the loessial uplands the Tama soils and the Dodgeville silt loam are the highest in nitrogen, while the Clinton and Fayette types are lower. On the terraces the Waukesha and Bremer soils are very high in nitrogen while the O'Neill and Judson types are low. On the bottomlands the Wabash loam is a little higher than the Cass loam. The Wabash silt loam is lower than the other types.

Again there is apparently some relationship between the nitrogen content of the soils and those characteristics which serve to determine the series. Those soils which are darker in color, more level in topography and which have heavier subsoils are richer in nitrogen. Thus, the Clyde silt loam is higher than the Carrington types and is darker in color, more level in topography and has a heavier subsoil. The Carrington soils are much better supplied than the Lindley and Shelby types, which is due to a darker color, a heavier subsoil and a less rough to steep topography. On the loessial uplands the Tama soils are darker than the Clinton and Fayette types and are better supplied with nitrogen. On the terraces the Waukesha and Bremer soils are darker in color than the O'Neill and have heavier subsoils, and they are richer in nitrogen.

The textural differences in soils also have an important influence on nitrogen content. Some comparisons of textural differences may be made here. On the drift uplands the Carrington silt loam is richer in nitrogen than the Carrington loam, while the latter type is much better supplied with nitrogen than the Carrington sandy loam. On the loessial uplands the Dodgeville silt loam is higher in nitrogen than the Dodgeville sandy loam, the Clinton silt loam is much better supplied than the Clinton very fine sandy loam. On the terraces the O'Neill loam is richer in the element than the O'Neill sandy loam. On the bottomlands the Wabash loam is much higher in nitrogen than the Wabash silt loam, which is contrary to the usual results and is probably due to some abnormal conditions pertaining to one of these samples. In general the results indicate that finer textured types such as silt loams are richer than loams and sandy loams, while loams are better supplied than sandy loams, sands and fine sands.

Apparently some of the soils of this county are not very well supplied with nitrogen, and in such cases the addition of some fertilizing materials supplying nitrogen is very necessary. On others of the soil types, however, there is no evidence of a lack of nitrogen and the supply would seem to be adequate for many years to come. However, nitrogen must not be disregarded when systems of permanent fertility are planned. There is a constant loss of nitrogen from soils which are under cultivation and unless some fertilizing material supplying the element is used at regular intervals, a deficiency will occur. This may happen on some of the soils in this county at a rather early date. It is very important, therefore, that some method be followed to keep up the nitrogen supply of these soils, if they are to continue to be satisfactorily productive.

Farm manure is the most important fertilizing constituent which can be applied to the land to prevent a deficiency of nitrogen. It returns to the soil much of the nitrogen which has been removed by the crops grown and, therefore, has large fertility value. On the coarse textured types and those which are low in nitrogen, the effects of farm manure will be of especially large value. Small applications may also be made with value to even the dark colored, better supplied types because of the effect of manure in stimulating the production of available plant food. Large applications of farm manure should not be made to the dark-colored, heavy soils, however.

Thoro utilization of all crop residues will also aid materially in keeping up the supply of nitrogen in the soil. These materials should not be burned or otherwise destroyed as they have large fertility value. The turning under of leguminous crops as green manures would also aid in keeping up the nitrogen supply of the land and increasing the content of this constituent. On the soil types which are low in nitrogen, the turning under of legumes as green manures would be of particularly large value. Green manuring is a very desirable practice on many of the soils of this county as a means of building up and maintaining the nitrogen content of the land.

Generally a rather distinct relationship is apparent between the nitrogen content of the soil and the organic carbon content or content of organic matter. The color of the soil generally indicates the content of organic matter and thus indirectly the content of nitrogen. Black soils are high in organic matter and are usually high in nitrogen, while light colored types are apt to be low in both these constituents. There is a wide variation in the color of the soils in Delaware County and hence wide differences in the content of organic carbon and nitrogen might be expected. The range in content of organic carbon is from 5,725 pounds per acre in the Lindley sandy loam up to 86,986 pounds in the Clyde silt loam.

The relationships between the various soil types and the organic carbon content are very similar to those which were noted in the case of nitrogen. Comparing the various soil groups, it seems that the bottomland types are better supplied with this constituent than are the upland soils, which might be expected. Those characteristics which determine soil series have an apparent effect on the organic matter content. The color of the soil, the topographic position and the subsoil characteristics are all important in determining the content of organic carbon. Thus, the Clyde silt loam on the drift upland is richer in organic matter than are the other upland types, while the Carrington soils are better supplied than the Thurston, Lindley and Shelby types. The Thurston soils are richer than the Lindley and Shelby types. On the loessial uplands the Tama soils and Dodgeville types are richer than the Clinton and Fayette soils. On the terraces the Waukesha and Bremer soils are higher than the O'Neill. On the bottomlands there is little difference between the Wabash and Cass soils. In general these differences are reflected in color, topographic position and subsoil characteristics.

Textural differences also have an effect on the content of organic matter. The Carrington silt loam is higher in organic matter than the loam, which in turn is much better supplied than the Carrington sandy loam. The Clinton silt loam is richer in organic matter than the Clinton very fine sandy loam, while the Dodgeville silt loam is better supplied than the Dodgeville sandy loam. The O'Neill loam is higher than the O'Neill sandy loam. On the bottomlands the Wabash loam is richer than the Wabash silt loam, which is contrary to the usual results, probably due, as was noted in the case of the nitrogen, to an abnormal condition in one of the samples analyzed. Generally the finer-textured types are higher in organic matter than the coarse-textured soils. Silt loams are better supplied than loams, while the latter types are richer in organic matter than sandy loams or loamy sands or very fine sandy loams.

Some of the soil types in the county are not very well supplied with organic matter and additions of fertilizing materials supplying this constituent are very necessary. On others of the soils, there is apparently a considerable amount of organic matter. It is necessary, however, to add organic matter regularly to all the soils of the county to keep up the supply. The use of farm manure is particularly desirable on the sandy, light-colored soils, but small amounts of farm manure will also be of value on the dark-colored, apparently richer soils. The thoro utilization of crop residues is essential in permitting of the maintenance of the organic matter content of the soil. The turning under of leguminous crops as green manures is very desirable on

many of the soils of this county, particularly on the light colored, coarse textured types, to increase the content of organic matter and to improve the fertility conditions. Green manuring should be practiced as a supplement to farm manure or as a substitute for that material.

The relationship between the organic carbon content and nitrogen indicates something of the rate at which plant food is being made available. If this relationship is not at the best, crops may suffer for the necessary plant food. In some of the Delaware County soils this relationship is not entirely satisfactory. On these types the application of farm manure would be of particularly large value in stimulating the production of available plant food. On all the soils of the county, however, farm manure brings about large crop increases and the value of this material as a fertilizer is very great. All the manure produced on the farm should be carefully preserved and applied to the land to permit of the best maintenance of fertility conditions in the soil.

No inorganic carbon content was found in any of the surface soils in this county. It is apparent, therefore, that the soils are generally lacking in lime, are acid in reaction and should be tested to determine their needs for lime. The amount of lime shown to be necessary should be supplied if the best crop growth, particularly of legumes, is to be secured.

The lime requirements shown in the tables are indicative only of the needs of the soil. Applications should be made only after the particular soil has been tested in order that the proper amount may be applied. Soils vary

TABLE V. PLANT FOOD IN DELAWARE COUNTY, IOWA, SOILS

Pounds per acre of 4 million pounds of subsurface soil (6⅔″–20″)

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	2,060	5,600	61,054	------	6,500
83	Carrington silt loam	2,060	6,900	71,923	------	5,500
84	Clyde silt loam	3,098	16,800	72,015	------	1,000
3	Carrington sandy loam	1,347	2,760	22,454	------	3,000
161	Lindley sandy loam	780	760	2,180	------	1,000
221	Shelby sandy loam	1,104	1,760	11,669	------	1,000
162	Thurston sandy loam	1,616	1,300	10,577	------	2,000
	LOESS SOILS					
120	Tama silt loam	1,454	4,360	33,768	------	6,000
177	Tama silt loam (light colored phase)	1,154	4,400	51,353	------	1,000
80	Clinton silt loam	1,131	2,240	13,634	------	4,000
222	Dodgeville sandy loam	1,185	3,200	34,856	------	5,000
163	Fayette silt loam	1,266	3,520	22,788	------	4,000
204	Dodgeville silt loam	1,642	8,320	88,249	------	1,000
178	Clinton very fine sandy loam	1,992	1,680	18,762	------	2,000
	TERRACE SOILS					
108	O'Neill loam	1,372	3,600	32,680	------	4,000
126	O'Neill sandy loam	1,239	6,400	13,859	------	2,000
75	Waukesha silt loam	2,074	3,080	40,889	------	4,000
88	Bremer silt loam	1,480	3,160	36,379	------	4,000
179	Judson loamy sand	1,347	1,760	12,000	------	4,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	3,016	11,480	122,721	------	2,000
18	Cass loam	3,422	8,120	85,585	------	4,000
49	Wabash loam	3,070	12,880	153,921	------	5,000

widely in lime requirement, and even within the same type wide differences may occur. The analyses given here merely indicate the general need of lime. Farmers are urged to have their soils tested and to apply the lime shown to be necessary by the tests, if they expect to secure the most satisfactory crop growth. One test will not be sufficient for all time, and every soil should be tested at least once in a rotation, preferably preceding the legume crop, if the supply of lime is to be maintained.

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 four million pounds of subsurface soil and six million pounds of subsoil per acre.

The lower soil layers in Delaware County are apparently not high in any of the essential plant food constituents, nor are they distinctly deficient in any case. There can be little effect, therefore, on the fertility of the soil, and the analyses of the surface soils may be considered to indicate quite definitely their needs. It seems unnecessary to consider the analyses of the lower soil layers in detail. They merely serve to emphasize the needs of the soils of the county as indicated in the discussion of the analyses of the surface soils.

Phosphorus fertilizers will certainly be needed in the future and may be of value in many cases at the present time. The supply of organic matter and nitrogen is low in some of the soils and in all the types it must be maintained thru a proper utilization of farm manure, crop residues and leguminous green

TABLE VI. PLANT FOOD IN DELAWARE 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	1,818	3,060	31,393	------	4,000
83	Carrington silt loam	1,677	3,120	30,508	------	4,000
84	Clyde silt loam	1,938	3,720	34,659	------	------
3	Carrington sandy loam	1,535	1,340	4,902	------	4,000
161	Lindley sandy loam	1,091	600	11,613	------	1,000
221	Shelby sandy loam	1,131	1,340	13,425	------	1,000
162	Thurston sandy loam	1,980	2,760	17,340	------	4,000
	LOESS SOILS					
120	Tama silt loam	1,980	3,360	22,315	------	4,000
177	Tama silt loam (light colored phase)	1,949	2,880	27,326	------	2,000
80	Clinton silt loam	2,139	2,520	7,687	------	5,000
222	Dodgeville sandy loam	1,495	1,560	18,163	------	4,000
163	Fayette silt loam	2,220	1,680	14,398	------	3,000
204	Dodgeville silt loam			No sample		
178	Clinton very fine sandy loam	3,354	2,040	4,902	------	1,000
	TERRACE SOILS					
108	O'Neill loam	2,301	5,040	16,687	------	1,000
126	O'Neill sandy loam	1,657	1,566	29,123	------	1,000
75	Waukesha silt loam	2,262	3,240	38,905	------	4,000
88	Bremer silt loam	3,960	2,040	16,192	------	3,000
179	Judson loamy sand	1,454	1,080	1,636	------	3,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	3,555	6,000	72,768	------	1,000
18	Cass loam	2,139	2,040	15,538	------	1,000
49	Wabash loam	2,988	6,840	65,071	------	3,000

manures. By the application of these materials, the types which are low in organic matter and nitrogen may be built up and made more productive. All the soil types are acid in reaction and in need of lime. They should certainly be tested, therefore, for lime needs and lime should be supplied as necessary before legumes are grown if the best results from these crops are to be secured. Tests should also be made at regular intervals, at least once in the rotation, in order to permit of the maintenance of the supply of lime in the soil. The beneficial effects of lime are often evidenced on the general farm crops grown on the farm as well as on the legume crops.

Greenhouse Experiments

Two greenhouse experiments were carried out on soils from Delaware County, in the attempt to secure some information regarding the needs of the soils and the value of certain fertilizing materials. The Carrington loam and the Carrington silt loam, the two most important types in the county, were used in this work. In addition, greenhouse experiments on the Tama silt loam from Benton County, on the Tama silt loam from Black Hawk County, on the light colored phase of the Tama silt loam from Dubuque County, on the Clinton silt loam from Wapello County and on the Clyde silt loam from Linn County are included, inasmuch as these types occur extensively in Delaware County. The results secured will undoubtedly be applicable to the soils of this county.

The treatments employed in all the experiments include the application of manure, lime, rock phosphate, superphosphate, a complete commercial fertilizer and muriate of potash. These materials were used in amounts which are ordinarily employed in the field and hence the results of these greenhouse experiments may be considered to indicate quite definitely the fertilizer effects which may be secured in the field. Manure was applied at the rate of 10 tons per acre, lime was added in sufficient amounts to neutralize the acidity of the soils, rock phosphate was used at the rate of 2,000 pounds per acre, superphosphate at the rate of 250 pounds per acre, a standard 2-12-2 complete commercial fertilizer at the rate of 300 pounds per acre and muriate of potash at the rate of 50 pounds per acre. Wheat and clover were grown in the experiments, the clover being seeded about one month after the wheat was up. In the experi-

Fig. 3. Clover on Carrington loam from Delaware County, greenhouse experiment.

TABLE VII. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, DELAWARE COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	5.5	21.2
2	Manure	6.9	20.6
3	Manure+limestone	5.8	29.8
4	Manure+limestone+rock phosphate	9.4	30.4
5	Manure+limestone+superphosphate	8.8	31.0
6	Manure+limestone+complete commercial fertilizer	9.1	29.2

ment on the light colored phase of the Tama silt loam from Dubuque County, only the yield of wheat was secured.

RESULTS ON THE CARRINGTON LOAM

The results of the experiment on the Carrington loam from Delaware County are given in table VII. Manure increased the yield of wheat but had little effect on the clover. Limestone with the manure showed no effect on the wheat but gave a large increase in the clover. Rock phosphate with the manure and lime had a large effect on the wheat and also on the clover. The superphosphate with the manure and lime showed a slightly smaller effect on the wheat but had a larger influence on the clover. The complete commercial fertilizer with the manure and lime brought about very similar effects on both crops, to those occasioned by the phosphates.

It is apparent from these results that this soil will respond very profitably to applications of farm manure. The use of lime is necessary as the soil is acid, and the best crop yields will not be secured on acid soils. A phosphate

Fig. 4. Wheat and clover on Carrington loam from Delaware County, greenhouse experiment.

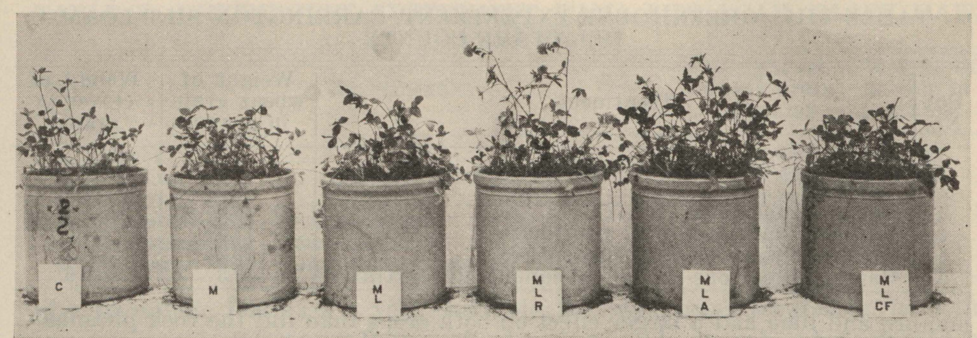

Fig. 5. Clover on Carrington silt loam from Delaware County, greenhouse experiment.

fertilizer may prove distinctly profitable on this type, and tests of rock phosphate and superphosphate are recommended. There is no evidence that the complete commercial fertilizer used in this work would be of any more value than a phosphorus carrier.

RESULTS ON THE CARRINGTON SILT LOAM

The results of the experiment on the Carrington silt loam from Delaware County are given in table VIII. The beneficial effects of manure are evidenced in the increased yields of wheat and clover which were secured. The effects on the clover were particularly noteworthy. Limestone applied with the manure had no effect on the wheat but brought about a pronounced increase in the clover. Rock phosphate with the manure and limestone increased the yield of wheat but showed little effect on the clover. The superphosphate with the

Fig. 6. Wheat and clover on Carrington silt loam from Delaware County, greenhouse experiment.

TABLE VIII. GREENHOUSE EXPERIMENT, CARRINGTON SILT LOAM, DELAWARE COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	8.0	15.8
2	Manure	8.9	18.6
3	Manure+limestone	8.9	21.4
4	Manure+limestone+rock phosphate	11.5	21.6
5	Manure+limestone+superphosphate	12.2	24.4
6	Manure+limestone+complete commercial fertilizer	12.3	22.0

manure and lime had a larger effect on both crops than did the rock phosphate. The complete commercial fertilizer with the manure and lime had a similar effect on the wheat to that brought about by the superphosphate but showed a slightly smaller influence on the clover.

These results indicate that the Carrington silt loam will be benefited materially by applications of manure, lime and phosphate fertilizers. The liberal application of manure is very desirable on this soil. The addition of lime is necessary for the best growth of general farm crops, particularly legumes, and the use of a phosphate fertilizer may bring about very profitable increases in yields. Tests of rock phosphate and superphosphate are recommended. It does not seem that a complete commercial fertilizer would be as economically profitable on this type as superphosphate.

RESULTS ON THE TAMA SILT LOAM FROM BENTON COUNTY

The results secured on the Tama silt loam from Benton County are given in table IX. The beneficial effects of manure on this soil are indicated by increases in the yields of both the wheat and the clover crop. The addition of lime with the manure increased the wheat yields slightly but brought about a very large increase in the clover. The rock phosphate with the manure and lime gave definite increases in both the wheat and clover crops. Superphosphate with the manure and lime gave about the same increase as the rock phosphate in both cases. On the wheat the complete commercial fertilizer had an effect very similar to that of the phosphates. The yield in the case of clover was not secured.

These data indicate the value of applications of manure, lime and a phosphate fertilizer to the Tama silt loam. The use of manure on this soil will bring about large beneficial effects on the growth of general farm crops. Lime will be particularly valuable on the legume in the rotation, as is indicated by the very beneficial effects on the clover grown in these pots. The application

TABLE IX. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, BENTON COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	14.8	12.1
2	Manure	15.0	15.5
3	Manure+lime	15.3	24.6
4	Manure+lime+rock phosphate	16.0	26.9
5	Manure+lime+superphosphate	16.3	25.8
6	Manure+lime+complete commercial fertilizer	16.1	----

TABLE X. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	12.00	8.0
2	Manure	12.65	31.0
3	Manure+lime	12.86	51.5
4	Manure+lime+rock phosphate	14.03	57.0
5	Manure+lime+superphosphate	12.72	64.5
6	Manure+lime+complete commercial fertilizer	13.67	59 5

of a phosphate fertilizer is very desirable, increases being secured on both the crops grown in this test. Both rock phosphate and superphosphate should be tested on this type under farm conditions. The complete commercial fertilizer does not seem to be any more desirable for use than the superphosphate or rock phosphate.

RESULTS ON THE TAMA SILT LOAM FROM BLACK HAWK COUNTY

The results secured on the Tama silt loam from Black Hawk County are given in table X. Manure increased the yields of wheat in this test and brought about a large increase in the clover. Lime with the manure showed little effect on the wheat but brought about large gains in the case of the clover. The rock phosphate with the manure and lime increased the yield of wheat considerably and showed an increase in the case of clover. The superphosphate showed no effect on the wheat but had a large influence on the clover. The complete commercial fertilizer increased both the wheat and clover yields, showing a slightly less effect than the rock phosphate on the wheat and a somewhat smaller effect than the superphosphate on the clover.

The results indicate the value of applications of manure to this soil and show that the use of lime may be very desirable for increasing the yields of legume crops. Rock phosphate or superphosphate will undoubtedly prove of value on this type; sometimes the superphosphate shows up to better advantage while in other cases the rock phosphate proves preferable. The complete commercial fertilizer does not seem to be as desirable for use as the phosphates.

RESULTS ON THE LIGHT COLORED PHASE OF THE TAMA SILT LOAM FROM DUBUQUE COUNTY

The results secured on the light colored phase of the Tama silt loam from Dubuque County are given in table XI. The addition of manure brought about a large effect on the wheat grown on this soil. Lime with manure gave a still further pronounced increase which is particularly interesting as wheat does not usually respond to applications of lime. The two phosphates both increased

TABLE XI. GREENHOUSE EXPERIMENT, TAMA SILT LOAM (LIGHT COLORED PHASE) DUBUQUE COUNTY

Pot No.	Treatment	Weight of wheat grain in grams
1	Check	3.073
2	Manure	5.296
3	Manure+lime	7.651
4	Manure+lime+rock phosphate	7.997
5	Manure+lime+superphosphate	8.655
6	Manure+lime+complete commercial fertilizer	9.397

the yield of wheat, the superphosphate showing up much better than the rock phosphate. The complete commercial fertilizer gave a larger effect than either of the phosphates. The gain over the superphosphates was hardly sufficient, however, to make the use of the complete fertilizer more profitable.

The results of this experiment indicate very definite beneficial effects from the application of manure to this soil and undoubtedly this material should be applied liberally. The addition of lime along with manure gave a distinct increase in the yield of wheat and would undoubtedly have large effects on other crops. The application of a phosphate fertilizer seems to be of distinct value on this soil, the superphosphate having a much greater effect than the rock phosphate. Definite conclusions regarding the relative value of these two phosphates should not be drawn, however, until tests are carried out under field conditions. While the complete commercial fertilizer used in this experiment gave somewhat better results than the phosphates, the differences secured could hardly be considered sufficient to warrant the use of the more expensive material, and for general farm conditions the use of one of the phosphorus carriers would undoubtedly be preferable.

RESULTS ON THE CLINTON SILT LOAM FROM WAPELLO COUNTY

The results secured on the Clinton silt loam from Wapello County are given in table XII. Manure showed a distinct influence on this soil, increasing the yield of wheat and causing a very large increase in the yield of clover. The application of lime with the manure gave an increase in the wheat, but the yield of clover under this treatment was not secured. Lime would ordinarily have a much greater effect on the legume crop than on a grain crop. The rock phosphate with the manure and lime slightly benefited the wheat and distinctly improved the clover. Superphosphate definitely increased the yields of the wheat and of the clover. The complete commercial fertilizer had a smaller effect than the superphosphate in the case of the wheat but brought about a larger effect on the clover.

It is evident that this soil will respond in a very profitable way to applications of manure, lime and a phosphate fertilizer. It is particularly in need of organic matter and the application of manure will, therefore, prove of especially large value. The type is acid in reaction and the use of lime is necessary for the best yields of general farm crops and particularly of legumes. The application of a phosphate fertilizer would be very desirable on this type, and tests of rock phosphate and superphosphate are recommended. It does not seem that the complete commercial fertilizer would be as economically profitable on this soil as the use of a phosphate.

TABLE XII. GREENHOUSE EXPERIMENT, CLINTON SILT LOAM, WAPELLO COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	17.39	38.0
2	Manure	18.69	44.0
3	Manure+limestone	19.27	----
4	Manure+limestone+rock phosphate	20.46	47.0
5	Manure+limestone+superphosphate	23.38	49.0
6	Manure+limestone+complete commercial fertilizer	21.89	52.0

TABLE XIII. GREENHOUSE EXPERIMENT, CLYDE SILT LOAM, LINN COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	13.94	39.0
2	Manure	15.73	62.0
3	Manure+lime	----	----
4	Manure+lime+rock phosphate	15.82	68.0
5	Manure+lime+superphosphate	16.00	71.0
6	Manure+lime+complete commercial fertilizer	16.49	69.0

RESULTS ON THE CLYDE SILT LOAM FROM LINN COUNTY

The results secured on the Clyde silt loam from Linn County are given in table XIII. The beneficial effect of manure on both the wheat and clover crops grown on this soil is evident, the influence being particularly noticeable in the case of the clover. The results on the pots where manure and lime were employed were abnormal and are not included here. The influence of the phosphates and of the complete commercial fertilizer is evidenced in the case of both crops, the superphosphate showing up somewhat better on the clover while the complete commercial fertilizer proved superior on the wheat.

This soil type is certainly benefited by manure, and large increases in the yields of general farm crops may be secured by its use. The type is acid in reaction and will respond to applications of lime. The addition of a phosphate fertilizer will undoubtedly prove of value, and tests of superphosphate and rock phosphate are recommended. It does not seem likely that a complete commercial fertilizer would be as desirable for use as one of the phosphates.

Field Experiments

No field experiments have been carried out in Delaware County, but the results of experiments under way in adjacent counties on the same soil types as those which occur extensively in Delaware County will be given in this report to indicate the effects of certain fertilizer treatments. The data obtained on the Carrington loam on the Waverly Field No. 2, Series I and II in Bremer County; on the Carrington loam on the Jesup Field in Black Hawk County; on the Carrington loam on the Eldora Field in Hardin County; on the Carrington silt loam on the Low Moor Field in Clinton County; on the Carrington silt loam on the Springville Field, Series I, in Linn County; on the Tama silt loam on the Hudson Field in Black Hawk County; and on the Clinton silt loam on the Princeton Field in Scott County are included. The results obtained on these fields may be considered definitely applicable to conditions in this county.

These field experiments are all planned with the idea of determining the relative value of various soil treatments and they are laid out on land which is representative of the individual soil type. 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 the crops to be sure that the results secured are accurate. On all of these fields, tests are included under both the livestock system and grain system of farming, manure being applied in the former and crop residues being utilized in the latter. Other fertilizing materials tested include limestone, rock phosphate, superphosphate, a complete commercial fertilizer and muriate of potash. Manure is applied at the rate of 8 tons per acre once in the rotation. Limestone is used in sufficient amounts to neutralize the acidity of the soil. Rock phosphate is added at the rate of 1,000 pounds per acre once in the rotation. Until 1925 this material was applied at the rate of 2,000 pounds per acre once in a four-year rotation. Superphosphate is applied at the rate of 150 pounds per acre three times in the four-year rotation. Until 1923 this material was applied at the rate of 200 pounds per acre annually. Until 1923 the old standard 2-8-2 complete commercial fertilizer was used, being applied at the rate of 300 pounds per acre annually. The new standard 2-12-2 brand is now being employed, the applications being made at the rate of 202 pounds per acre annually, thus supplying the same amount of phosphorus as that contained in the superphosphate. The muriate of potash is applied at the rate of 50 pounds per acre.

THE WAVERLY FIELD

The results secured from the field experiment on the Carrington loam on the Waverly Field No. II, Series I, in Bremer County, are given in table XIV. The beneficial influence of manure on this soil is shown by the increased crop yields secured in practically every season. In some cases very large gains were noted, as on the clover in 1919, on the corn in 1924 and 1927, and on the oats in 1928. Lime with manure brought about increased crop yields in practically

TABLE XIV. FIELD EXPERIMENT, CARRINGTON LOAM, BREMER COUNTY, WAVERLY FIELD, NO. 2, SERIES I

Plot No.	Treatment	1918 Corn bu. per A. (1)	1919 Clover tons per A.	1920 Corn bu. per A. (2)	1921 Oats bu. per A. (3)	1922 Clover tons per A. (4)	1923 Corn bu. per A. (5)	1924 Corn bu. per A. (6)	1925 Oats bu. per A. (7)	1926 Clover tons per A. (8)	1927 Corn bu. per A.	1928 Oats bu. per A.
1	Check	42.8	1.50	47.8	25.7	2.22	---	11.0	---	---	40.4	35.2
2	Manure	61.0	1.75	56.5	34.3	2.20	---	24.7	63.9	---	53.3	52.2
3	Manure+lime	64.9	1.10	57.5	50.6	2.32	---	30.4	77.7	---	65.8	45.4
4	Manure+lime+rock phosphate	65.5	2.60	58.0	40.3	2.10	---	34.3	87.8	---	63.4	61.3
5	Manure+lime+complete commercial fertilizer	72.1	2.35	44.0	35.7	2.78	---	42.1	103.3	---	62.9	57.9
6	Manure+lime+superphosphate	67.2	2.85	47.0	42.0	2.90	---	38.2	89.3	---	67.3	65 8
7	Check	55.1	1.55	36.6	30.6	1.76	---	19.2	59.9	---	36.7	40.8
8	Crop residues	49.6	1.05	39.6	20.3	1.24	---	18.8	51.7	---	38.6	34.0
9	Crop residues+lime	66.2	1.50	40.8	30.4	1.84	---	20.3	62.1	---	55.5	44.2
10	Crop residues+lime+rock phosphate	70.0	1.75	41.6	40.6	2.16	---	20.5	85.3	---	59.8	54.5
11	Crop residues+lime+superphosphate	88.2	2.55	43.3	38.4	2.70	---	23.1	86.9	---	61.4	58.9
12	Crop residues+lime+complete commercial fertilizer	88.6	2.10	45.8	46.0	2.70	---	22.4	86.5	---	51.6	58.9
13	Check	79.7	1.55	35.1	26.7	1.48	---	16.3	53.4	---	33.4	38.6

(1) Six tons lime, fall 1917.
(2) Soybeans planted in corn, both crops poor. Wet spring injured plots in center series. Plots 5 and 6 and crop residue plots, weedy.
(3) Plot 3 too high, many morning glory vines on plot.
(4) Stand uneven on 2 and 4.
(5) No crop yields secured owing to drought.
(6) Crop damaged by frost—phosphate plots showed more maturity.
(7) Barley seeded by mistake on plot 1. Unable to account for high yield on plot 5.
(8) Field pastured—no results taken.

all seasons, particularly on the oats in 1921 and 1925 and on the corn in 1927. The yield on plot 3 in 1919 was evidently abnormal.

The rock phosphate with the manure and lime increased the crop yields to a very pronounced extent in some seasons but in one or two cases showed no beneficial effects. The clover in 1919 was greatly increased and this was true also of the oats in 1925 and 1928 and of the corn in 1927. The superphosphate showed a greater effect than the rock phosphate in most seasons. The differences, however, were not large; in one case the superphosphate showed less effect than the rock phosphate and in one instance the results were almost exactly alike. The complete commercial fertilizer had a greater influence than the superphosphate in one or two cases but in general the effects were similar. Large increases were noted, however, in 1925 from the complete commercial fertilizer.

The crop residues had little effect on the various crops grown. Lime with the residues increased the crop yields in all cases and in some instances very large gains were noted, particularly on the clover in 1919, and 1922, and on the corn in 1927. Large effects were also shown on the oats in 1921, 1925 and 1928. The rock phosphate with the crop residues and lime increased the crop yields considerably in practically every case; the largest influence was noted on the clover crop, and on the oats in 1925 and 1928. The superphosphate with the

TABLE XV. FIELD EXPERIMENT, CARRINGTON LOAM, BREMER COUNTY, WAVERLY FIELD, NO. 2, SERIES II

Plot No.	Treatment	1918 Corn bu. per A. (1)	1919 Oats bu. per A.	1920 Clover tons per A. (2)	1921 Clover and Timothy tons per A.	1922 Corn bu. per A. (3)	1923 Corn bu. per A. (4)	1924 Oats bu. per A. (5)	1925 Sweet Clover tons per A.	1926 Alfalfa tons per A. (6)	1927 Alfalfa tons per A. (7)	1928 Alfalfa tons per A. (8)
1	Check	38.5	39.8	0.47	1.03	39.4	25.0	42.8	0.39	---	0.51	0.35
2	Manure	54.0	49.3	0.67	1.30	55.7	40.2	49.7	0.45	0.76	1.46	1.87
3	Manure+lime	56.8	61.9	1.36	1.87	62.3	57.0	66.4	2.66	1.28	2.52	3.00
4	Manure+lime+rock phosphate	57.2	46.4	1.66	1.98	63.1	62.0	64.9	2.72	1.61	3.19	3.18
5	Manure+lime+superphosphate	60.5	57.8	2.05	2.19	64.0	60.7	75.8	3.03	1.65	3.18	2.88
6	Manure+lime+complete commercial fertilizer	61.3	61.9	1.99	2.47	62.9	63.0	65.3	3.03	1.35	3.12	3.30
7	Check	48.7	35.4	0.84	1.17	45.7	34.2	42.5	0.62	0.67	0.96	1.29
8	Crop residues	46.4	39.4	0.67	1.09	41.4	34.0	48.3	0.62	0.69	0.79	1.21
9	Crop residues+lime	50.0	48.3	0.87	1.26	50.6	45.2	55.5	2.93	1.10	1.72	2.40
10	Crop residues+lime+rock phosphate	56.7	40.8	1.14	1.44	52.0	46.5	74.7	3.02	1.11	2.04	2.35
11	Crop residues+lime+superphosphate	48.7	47.3	1.11	1.63	51.4	47.5	70.9	3.02	1.36	2.21	2.55
12	Crop residues+lime+complete commercial fertilizer	42.7	53.5	1.32	2.10	60.8	50.7	51.2	2.96	1.31	2.55	3.14
13	Check	33.4	32.9	0.33	0.87	34.8	43.2	37.8	0.45	0.69	0.36	0.87

(1) Six tons lime, fall 1917. Heavy rains washed 11, 12 and 13 badly.
(2) Plots 1 and 2 poorer in fertility than other plots.
(3) Dry season.
(4) Plot 13 high, probably due to manure application made thru error.
(5) Low yield on plot 12 due to part of crop lost in threshing.
(6) Grasshoppers destroyed the crop on plot 1 and damaged west side of all plots.
(7) Two cuttings. First cutting mostly timothy on plots 1 and 13. Timothy seeded in 1926 to thicken stand.
(8) Two cuttings. First cutting mostly timothy on plots 1 and 13.

crop residues and lime had a larger effect than the rock phosphate in practically every season. In some seasons the gains were pronounced, as on the clover in 1919 and 1922. In other cases the differences were not large. The complete commercial fertilizer with the crop residues and lime had about the same effect as did the superphosphate, showing a slightly greater influence in some cases and a smaller effect in others.

The results secured on the Carrington loam on the Waverly Field, Series II, in Bremer County are given in table XV. Here again manure resulted in large increases in crop yields in practically every season. The clover in 1920 and 1921, the corn in 1922 and 1923, and the alfalfa in 1927 and 1928 showed the largest influence from the use of manure. The application of lime with the manure brought about distinct gains in the crop yields in every season. In some cases the gains were very large, as on the clover in 1920 and 1921, on the sweet clover in 1925, on the corn in 1923, on the oats in 1924, and on the alfalfa in 1926, 1927 and 1928.

The rock phosphate with the manure and lime had a beneficial effect on the crop yields in most seasons. The differences, however, were small, and in some cases no gains were noted. The superphosphate with the manure and lime increased the yields considerably in most seasons, the largest effect being noted on the clover and alfalfa, altho there was also a large effect on the oats in 1924. The complete commercial fertilizer showed a somewhat greater effect than the superphosphate in some cases but in several instances did not bring about as large increases.

The crop residues had little effect on the crop yields, small increases being noted only in one or two cases. Lime with the residues increased the crop yields in a very pronounced way, in some cases bringing about large increases, as on the sweet clover in 1925 and on the alfalfa in 1926, 1927 and 1928. The rock phosphate with the crop residues and lime increased the yields in most cases, the influence being considerable on the clover crop and on the oats in 1924. The superphosphate with the crop residues and lime showed a larger effect than the rock phosphate in one or two cases, but the differences were small and the returns were generally about the same. The complete commercial fertilizer showed a larger effect than the superphosphate in some cases, particularly on the clover and timothy in 1921 and on the alfalfa in 1927 and 1928, but in other instances there were smaller effects from the complete fertilizers.

From these results it is apparent that the liberal addition of manure to this type is very desirable for the best growth of general farm crops. The type is acid in reaction and the application of lime is essential if the best crops of legumes are to be secured. The addition of a phosphate fertilizer is very desirable and often results in large increases in crop yields. The use of a complete commercial fertilizer does not seem to be as desirable as the use of a phosphate.

THE JESUP FIELD

The results secured in the field experiments on the Carrington loam on the Jesup Field in Black Hawk County are given in table XVI.

The beneficial effect of manure on this soil is evidenced by the increased crop yields secured in practically all seasons. Large gains resulted from the applications of manure on the clover in 1919, on the clover and timothy in 1920, and on the corn in 1921, 1922, 1926 and 1927. Lime with the manure proved of value, in many cases considerable increases in the yields of crops being secured. The oats in 1918, the clover and timothy in 1920, the oats in 1923, the clover in 1924, the corn in 1927 and the oats in 1928, showed pronounced effects from the addition of the lime.

TABLE XVI. FIELD EXPERIMENT, CARRINGTON LOAM, BLACK HAWK COUNTY, JESUP FIELD, SERIES II

Plot No.	Treatment	1918 Oats bu. per A. (1)	1919 Clover tons per A.	1920 Clover and Timothy tons per A. (2)	1921 Corn bu. per A.	1922 Corn bu. per A.	1923 Oats bu. per A. (3)	1924 Clover tons per A. (4)	1925 Clover tons per A. (5)	1926 Corn bu. per A. (6)	1927 Corn bu. per A. (7)	1928 Oats bu. per A. (8)
1	Check	71.9	1.17	0.50	58.7	51.4	31.7	0.92	---	47.2	28.2	45.4
2	Manure	71.6	2.08	0.85	72.8	65.6	29.4	1.06	---	60.5	34.2	45.4
3	Manure+lime	83.1	1.92	1.20	77.6	71.1	37.3	1.26	---	60.0	45.9	53.3
4	Manure+lime+rock phosphate	81.8	1.86	1.15	78.1	73.4	41.8	1.29	---	72.5	44.9	63.5
5	Manure+lime+superphosphate	76.1	2.22	1.12	75.5	73.4	45.3	1.65	---	73.3	42.9	66.9
6	Manure+lime+complete commercial fertilizer	77.2	2.80	1.25	78.7	77.6	44.2	1.60	---	65.3	40.3	62.4
7	Check	60.8	1.38	0.47	54.0	53.7	34.0	0.58	---	34.1	17.2	49.9
8	Crop residues	64.0	1.36	0.52	56.5	56.0	38.3	0.88	---	---	---	---
9	Crop residues+lime	64.9	1.15	0.42	46.4	52.0	36.3	1.15	---	---	---	---
10	Crop residues+lime+rock phosphate	63.6	1.53	0.42	60.8	60.8	38.7	1.23	---	---	---	---
11	Crop residues+lime+superphosphate	62.5	1.53	0.60	67.6	62.6	38.3	1.62	---	---	---	---
12	Crop residues+lime+complete commercial fertilizer	75.7	1.77	0.70	72.8	70.2	38.3	1.67	---	---	---	---
13	Check	67.8	1.20	0.65	60.2	55.4	34.0	1.18	---	---	---	---

(1) Three and one-half tons lime applied.
(2) Plots 9 and 10 in swale and poorly drained.
(3) Oats thin, dry season.
(4) Plot 7 poor, due to poor drainage; plot 13 high, due to old yard location.
(5) Plots were pastured.
(6) Crop residue plots were left in pasture and not plowed.
(7) Plots 8, 9, 10, 11, 12 and 13 were still in pasture.
(8) Plots 8, 9, 10, 11, 12 and 13 in pasture.

Rock phosphate with the manure and lime increased the crop yields in several seasons, altho in general no large effects were secured. Only with the corn in 1926 and the oats in 1928 were there any large increases from the rock phosphate. In most cases the gains were small and in one or two seasons no increases at all were secured. The superphosphate with the manure and lime had a larger effect than the rock phosphate in one or two instances, as for example on the clover in 1919 and 1924, and on the oats in 1928. In most seasons small differences between the effects of the two phosphates were noted. The complete commercial fertilizer increased the crop yields slightly more than did the superphosphate in most seasons. In general, however, the differences were slight, and in one or two cases the complete commercial fertilizer showed less effect than the superphosphate.

The crop residues had little effect on the crops grown in most seasons. In one or two cases, increases were secured, as on the clover in 1924. Lime with the crop residues increased the crop yields only in one or two seasons. The

TABLE XVII. FIELD EXPERIMENT, CARRINGTON LOAM, HARDIN COUNTY, ELDORA FIELD, SERIES 200

Plot No.	Treatment	1917 Oats bu. per A. (1)	1918 Clover tons per A. (2)	1919 Corn bu. per A.	1920 Corn bu. per A. (3)	1921 Oats bu. per A.	1922 Clover tons per A. (4)	1923 Corn bu. per A. (5)	1924 Corn bu. per A. (6)	1925 Oats bu. per A. (7)	1926 Oats bu. per A.	1927 Corn bu. per A.	1928 Corn bu. per A.
1	Check	60.1	0.54	46.4	60.9	26.6	1.17	41.5	31.6	38.1	20.6	39.5	53.7
2	Manure	66.4	0.90	50.0	62.5	38.0	1.38	37.6	30.3	48.6	20.5	45.0	56.3
3	Manure+lime	65.7	1.00	51.8	65.6	41.8	1.31	40.0	23.3	48.3	27.7	38.0	62.6
4	Manure+lime+rock phosphate	72.6	1.85	53.6	71.8	50.3	2.06	42.1	30.0	69.0	30.3	49.8	65.7
5	Manure+lime+superphosphate	85.5	1.51	57.2	68.7	48.7	2.57	46.6	30.0	72.6	37.3	51.2	60.9
6	Manure+lime+complete commercial fertilizer	80.0	1.48	51.7	59.3	54.6	2.61	53.2	28.1	79.9	41.9	48.6	58.8
7	Check	62.0	0.45	48.8	42.1	36.9	1.88	38.2	18.3	49.7	28.4	26.6	36.4
8	Crop residues	61.8	0.41	50.7	35.9	32.3	1.80	36.9	18.3	49.0	27.5	26.6	31.9
9	Crop residues+lime	63.0	0.47	50.8	35.9	29.2	1.41	43.2	19.0	51.5	26.4	23.0	38.8
10	Crop residues+lime+rock phosphate	69.2	0.49	60.0	45.3	22.0	2.13	40.5	19.7	59.4	27.2	33.9	40.5
11	Crop residues—lime+superphosphate	67.6	0.74	62.5	48.4	32.2	2.32	40.0	21.7	56.6	27.7	36.4	35.9
12	Crop residues+lime+complete commercial fertilizer	66.4	0.51	55.3	59.3	37.2	2.60	46.6	21.7	62.4	35.0	39.9	39.5
13	Check	60.0	0.38	52.1	48.4	28.6	1.68	31.5	10.0	45.0	28.4	31.4	35.4

(1) Three tons of lime in 1916.
(2) Crop poor, dry season.
(3) Plots 5, 6, 7, 8 and 9 poor, due to wet spring. Limed 3 tons per acre.
(4) Poor stand on plots 1, 2, 3.
(5) Dry season, poor stand.
(6) Poor drainage on plot 13.
(7) Plots 7, 8 and 13 are poorly drained.

rock phosphate with the crop residues and lime brought about pronounced increases in the yields of crops in several cases, but in two instances no effects were noted. The superphosphate with the crop residues and lime had a greater effect than the rock phosphate in most seasons. The differences in favor of the superphosphate in some cases were quite pronounced, as on the clover and timothy in 1920, and on the clover in 1924. The complete commercial fertilizer with the crop residues and lime had a larger effect on the crops grown in practically every season. In some cases considerable increases were secured.

These results as a whole confirm the conclusions drawn from the experiments on the same soil type on the Waverly Field and indicate the value of applications of manure, lime and a phosphate fertilizer to this soil.

THE ELDORA FIELD

The results secured in the field experiment on the Carrington loam on the Eldora Field, Series 200, in Hardin County are given in table XVII.

The application of manure brought about pronounced increases in the yields of crops secured on this field in practically all seasons. In some cases very large gains were noted, as on the clover in 1918, on the oats in 1921, on the clover in 1922 and on the oats in 1925. The yields of corn were appreciably increased in practically all seasons. Only in one or two cases were no increases noted. The application of lime with the manure increased the crop yields in most seasons, showing the largest beneficial effect on the clover in 1918, on the oats in 1926 and on the corn in 1928. In several seasons no gains from the use of lime were noted.

The application of rock phosphate with the manure and lime brought about pronounced increases in the yields of crops in all seasons. Large effects were evidenced on the clover in 1918 and 1922. The oats in 1917, 1921, 1925 and 1926 were increased, the largest effect being shown on this crop in 1925. Corn was benefited to a considerable extent in all seasons, the largest effects appearing on the crop in 1927. The superphosphate applied with the manure and lime brought about a larger beneficial effect on the crop yields in some seasons than did the rock phosphate. In other cases, however, the effects were less pronounced. There was a much greater effect from the superphosphate on the oats in 1917 and 1926, and on the clover in 1922. Greater effects were also shown on the corn in 1919, 1923 and 1927, but the differences in the effects of the two phosphates were small. The complete commercial fertilizer with the manure and lime had about the same effect as the superphosphate in most cases, showing up to somewhat greater advantage in some seasons and having a smaller effect in others. The differences, however, were not very great.

The crop residues had little effect on the crops grown in most seasons. Lime with the crop residues brought about some increases but the effects were not very pronounced. Rock phosphate with the crop residues and lime increased the yields in practically all cases, especially on the corn in 1919, on the clover in 1922 and on the corn in 1927. In a few cases no gains were secured. The superphosphate with the crop residues and lime showed larger effects than the rock phosphate in most seasons. The greatest benefits were evident on the clover in 1918 and 1922, on the oats in 1921, and on the corn in 1919, 1920, 1924 and 1927. The differences in the case of the corn yields are not very pronounced, however, and in one or two cases the rock phosphate showed up to better advantage. The complete commercial fertilizer with the crop residues and lime had a greater effect than the superphosphate in a number of cases, showing up particularly well on the corn in 1920 and in 1923, on the clover in 1922 and on the oats in 1925 and 1926. The differences in the other seasons were small and mostly slightly in favor of the complete fertilizer. The gains, however, hardly warrant the application of the more expensive complete fertilizer.

The results secured in this experiment confirm those previously obtained on the Carrington loam and indicate definitely the value of manure, lime and a phosphate fertilizer when applied to this type.

THE LOW MOOR FIELD

The results secured in the field experiment on the Carrington silt loam on the Low Moor Field in Clinton County are given in table XVIII.

Manure increased crop yields in every season, very large increases being noted on the clover and timothy in 1919 and on the corn in 1922, 1923, 1927 and 1928. Lime applied with manure brought about further increases in crop yields in every case. The clover and timothy crop showed the largest beneficial

TABLE XVIII. FIELD EXPERIMENT, CARRINGTON SILT LOAM, CLINTON COUNTY, LOW MOOR FIELD

Plot No.	Treatment	1918 Barley bu. per A. (1)	1919 Clover and Timothy tons per A. (2)	1920 Timothy tons per A. (3)	1921 Timothy tons per A. (4)	1922 Corn bu. per A. (5)	1923 Corn bu. per A.	1924 Corn bu. per A. (6)	1925 Barley bu. per A. (7)	1926 Clover tons per A. (8)	1927 Corn bu. per A.	1928 Corn bu. per A.
1	Check	33.0	2.07	1.98	1.08	57.4	44.3	32.0	30.8	---	22.4	40.3
2	Manure	43.0	2.31	2.13	1.24	67.7	53.9	32.5	32.6	---	40.5	54.9
3	Manure+lime	44.4	2.46	2.77	1.39	72.3	59.6	41.6	44.6	---	46.9	60.6
4	Manure+lime+rock phosphate	43.0	2.71	2.64	1.32	75.2	68.0	42.9	54.8	---	58.2	61.6
5	Manure+lime+superphosphate	47.2	2.73	2.64	1.41	72.7	68.4	44.5	55.9	---	53.8	64.8
6	Manure+lime+complete commercial fertilizer	48.6	2.67	2.81	1.41	74.3	66.0	41.1	54.4	---	58.0	64.1
7	Check	38.7	2.58	2.46	1.12	64.0	54.8	25.3	29.0	---	26.1	37.5
8	Crop residues	40.0	2.58	2.28	1.09	63.7	53.2	25.6	31.6	---	31.9	36.2
9	Crop residues+lime	38.7	2.80	2.47	1.38	63.1	64.9	37.6	37.4	---	30.0	53.8
10	Crop residues+lime+rock phosphate	42.6	2.94	2.94	1.51	57.4	68.2	48.0	43.2	---	41.7	61.5
11	Crop residues+lime+superphosphate	48.6	2.95	2.74	1.44	61.7	68.5	48.8	36.3	---	53.9	65.4
12	Crop residues+lime+complete commercial fertilizer	44.4	3.77	2.88	1.45	51.4	64.3	44.5	45.3	---	54.9	62.2
13	Check	42.6	---	2.52	1.39	47.1	57.3	30.7	30.8	---	33.0	41.5

(1) Three and one-half tons lime applied.
(2) Plot 13 low, receives wash from rest of series.
(3) Limed September 20, 4 tons.
(4) Heavier yields on crop residue plots due to topography.
(5) Plots 10 to 13 damaged by hogs.
(6) Low yields on plot 7 and 8 could not be accounted for.
(7) Low yield on plot 11 could not be accounted for.
(8) Pastured.

effect, but definite increases were also secured on the other crops grown on the field.

The use of rock phosphate with the manure and lime brought about very considerable increases in the yields of crops in most seasons. In one or two cases no increases were noted. Superphosphate with the manure and lime had larger effects than the rock phosphate in practically all cases. The differences, however, were not very large. The complete commercial fertilizer had very much the same effect as the superphosphate, proving slightly preferable in some seasons but having smaller effects in others.

The crop residues showed little effect on the yields of the various crops, bringing about slight increases in certain cases. Lime with the crop residues increased the yields to a very noticeable extent in some seasons, as for example on the clover and timothy in 1919, on the timothy in 1920 and 1921, and on the corn in 1923, 1924 and 1928. The rock phosphate applied with the lime and crop residues increased crop yields in practically all cases. In some instances very considerable increases were noted, as on the timothy in 1920 and 1921, and on the corn in 1924 and 1927. The superphosphate with the crop residues and lime showed larger effects than the rock phosphate in several cases but in one or two instances it had a smaller beneficial effect than the rock phosphate. The complete commercial fertilizer had much the same influence as the superphosphate, except in 1919 when it brought about a much larger effect on the clover and timothy.

These data indicate quite definitely the value of applications of manure, lime and a phosphorus fertilizer to this soil type. Large increases in crop yields follow the use of manure. The type is acid and in need of lime and the addition of a phosphate fertilizer is very desirable for the best crop yields.

THE SPRINGVILLE FIELD

The results secured on the Carrington silt loam on the Springville Field, Series I, in Linn County, are given in table XIX.

Beneficial effects of manure on this soil are definitely shown by these results. Considerable increases in crop yields were secured from the use of this material in practically all cases. In some seasons the crops were increased to a very large extent, as was the case with the corn in 1922, the oats in 1927, and the clover in 1918 and 1928. The application of lime with the manure increased crop yields in most seasons. In several seasons large beneficial effects were secured from the use of lime, as on the corn in 1920, on the oats in 1925, and on the clover in 1922 and 1928.

The rock phosphate with the manure and lime showed very definite increases on crop yields in practically all seasons. In some cases the gains were striking, as on the clover in 1922, on the corn in 1923, on the oats in 1927, and on the clover and timothy in 1928. The superphosphate with the manure and lime gave larger increases than the rock phosphate in some cases but in others the

TABLE XIX. FIELD EXPERIMENT, CARRINGTON SILT LOAM, LINN COUNTY, SPRINGVILLE FIELD, SERIES I

Plot No.	Treatment	1918 Clover tons per A. (1)	1919 Corn bu. per A. (2)	1920 Corn bu. per A. (3)	1921 Oats bu. per A.	1922 Clover tons per A. (4)	1923 Corn bu. per A. (5)	1924 Corn bu. per A. (6)	1925 Oats bu. per A.	1926 Corn bu. per A.	1927 Oats bu. per A.	1928 Clover and Timothy tons per A.
1	Check	2.25	58.6	46.5	44.8	1.37	40.2	---	53.9	41.6	21.5	0.71
2	Manure	2.47	64.8	63.3	36.4	1.47	51.2	---	72.4	49.3	33.8	1.06
3	Manure+lime	2.40	63.7	51.1	46.9	1.35	55.9	---	57.4	46.4	31.0	0.96
4	Manure+lime+rock phosphate	2.70	60.8	66.1	42.8	2.02	60.2	---	71.6	50.4	45.5	1.89
5	Manure+lime+superphosphate	2.70	67.1	60.8	46.3	2.14	59.7	---	68.6	47.4	41.9	1.92
6	Manure+lime+complete commercial fertilizer	2.70	64.5	61.0	49.2	1.99	60.7	---	74.1	47.4	37.8	1.48
7	Check	1.65	60.0	51.9	36.9	1.35	40.0	---	43.6	34.4	35.1	0.73
8	Crop residues	2.05	62.5	55.0	42.8	1.40	46.2	---	47.4	37.8	36.8	0.91
9	Crop residues+lime	2.02	49.4	59.6	38.9	1.56	44.2	---	62.1	38.6	41.9	1.05
10	Crop residues+lime+rock phosphate	2.16	55.7	58.5	43.6	1.98	54.4	---	64.8	36.8	52.0	1.41
11	Crop residues+lime+superphosphate	2.47	55.4	58.5	48.4	2.10	43.5	---	62.2	37.0	48.5	1.49
12	Crop residues+lime+complete commercial fertilizer	2.19	33.1	57.3	37.8	2.04	44.7	---	72.4	38.6	56.6	1.22
13	Check	1.80	45.7	41.1	36.0	1.51	36.1	---	45.3	30.9	45.5	0.67

(1) Three and one-half tons lime, fall 1917.
(2) Plots 10, 11, 12 and 13 on low ground, poor stand.
(3) Plot 2, small ditch, abnormal yield.
(4) Clover down badly on 5 and 6, and 11 and 12; only 85 percent could be cut.
(5) Season dry.
(6) Field was replanted and corn did not mature; no yields taken.

rock phosphate proved somewhat superior. The differences were small, however, in all instances. The complete commercial fertilizer showed slightly smaller effects than the superphosphate in some seasons but in other seasons had a somewhat larger effect.

The crop residues brought about slight increases in the yields in most cases. Lime with the residues had a beneficial effect in several cases, the largest influence being secured on the oats in 1925, and on the clover in 1922 and 1928. Rock phosphate with the crop residues and lime had a beneficial effect on the crop yields in all but two cases. In some seasons the influence was very large, as for example on the clover in 1922, on the corn in 1923, on the oats in 1927, and on the clover and timothy in 1928. Superphosphate with the crop residues and lime showed larger effects than rock phosphate in several seasons but in others the influence was very similar to that secured with the rock phosphate. In one case there was a very pronounced difference in favor of the rock phosphate. The complete commercial fertilizer showed a smaller effect than the superphosphate in most seasons and in three cases where a larger influence was exerted, the differences were not large enough to be of significance.

It is apparent from these results that this soil type will respond profitably to applications of manure, lime and a phosphate fertilizer. Conclusions reached in the discussion of the results secured on the Low Moor Field are thus confirmed.

THE HUDSON FIELD

The results secured on the Tama silt loam on the Hudson Field in Black Hawk County are given in table XX.

The value of manure on this soil is evidenced by the results secured on the various crops grown on this field. Increased yields were secured in every season from the use of manure and in many cases the increases were very large. The application of lime with the manure brought about increases in crop yields in every case, the legume crop showing particularly large benefits from the application of the lime.

The rock phosphate with manure and lime increased the yields of crops in most seasons, the effect being particularly evidenced on the oats in 1919, on the corn in 1920 and on the oats in 1924. The superphosphate with the manure and lime showed slightly larger effects than did the rock phosphate on the clover and timothy in 1925 and 1926, and on the corn in 1927 and 1928, but in other seasons the increases brought about by the phosphates were very similar. The complete commercial fertilizer had a larger effect than the superphosphate in one or two cases, notably on the oats in 1922, and on the corn in 1923 and 1928. In other seasons, however, the beneficial effects were less pronounced than those brought about by the superphosphate.

The crop residues showed little effects on the yields, increases being noted only in one or two cases. Lime with the crop residues increased the crop yields in every season, showing large effects on the clover and timothy in 1925 and 1926, and on the corn in 1927 and 1928. Beneficial effects were also evident in other seasons on the oats and corn. Rock phosphate applied with the residues and lime increased crop yields in several seasons. In a few cases no gains were noted. Superphosphate with the crop residues and lime showed very similar

TABLE XX. FIELD EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY, HUDSON FIELD, SERIES II

Plot No.	Treatment	1918 Corn bu. per A. (1)	1919 Oats bu. per A.	1920 Oats bu. per A. (2)	1921 Corn bu. per A. (3)	1922 Oats bu. per A. (4)	1923 Corn bu. per A. (5)	1924 Oats bu. per A.	1925 Clover and Timothy tons per A.	1926 Timothy tons per A. (6)	1927 Corn bu. per A.	1928 Corn bu. per A. (7)
1	Check	45.8	47.6	53.2	---	44.8	54.0	40.3	1.43	0.88	45.7	50.8
2	Manure	49.3	54.7	62.8	---	53.1	59.6	50.6	1.64	1.16	64.3	57.2
3	Manure+lime	54.4	59.2	67.4	---	59.6	65.2	52.2	2.03	1.21	71.2	66.8
4	Manure+lime+rock phosphate	56.5	64.9	73.3	---	58.1	61.4	63.4	2.02	1.55	66.3	50.7
5	Manure+lime+superphosphate	57.4	62.2	73.3	---	53.2	59.6	63.7	2.25	1.61	76.3	58.4
6	Manure+lime+complete commercial fertilizer	58.5	57.5	72.4	---	62.2	68.4	60.0	2.09	1.64	75.6	64.4
7	Check	56.9	62.2	44.0	---	41.4	54.8	50.6	1.84	1.21	57.8	49.8
8	Crop residues	54.7	62.2	65.2	---	49.0	53.1	49.5	1.69	1.22	66.3	45.5
9	Crop residues+lime	57.9	64.6	71.3	---	62.4	66.7	57.7	2.27	1.66	70.5	51.3
10	Crop residues+lime+rock phosphate	62.8	58.1	74.9	---	59.6	65.7	66.4	2.32	1.70	74.1	59.3
11	Crop residues+lime+superphosphate	55.6	55.8	74.9	---	64.4	62.8	60.9	2.36	1.79	70.2	58.5
12	Crop residues+lime+complete commercial fertilizer	52.5	57.5	74.1	---	71.3	62.8	61.5	2.52	2.03	55.9	63.6
13	Check	54.5	57.0	71.3	---	59.7	50.2	48.7	1.94	1.43	55.4	47.1

(1) Four tons of lime. Hail damaged corn.
(2) Yield on plot 7 evidently an error.
(3) Corn cut and put in silo.
(4) Not very ripe when cut.
(5) Dry season.
(6) High yields on crop residue series due to lower ground and more moisture.
(7) Large number of missing hills on plot 4.

effects to those brought about by the rock phosphate, the increases being somewhat more pronounced in some seasons but not so definite in others. The complete commercial fertilizer had a greater effect than the superphosphate in several cases, particularly on the clover and timothy in 1925 and 1926. In several other seasons the effect was less than that of the phosphate.

The Tama silt loam apparently will respond in a very large way to applications of farm manure and liberal applications of this material should be applied to bring about the best growth of general farm crops. The use of lime with manure is very desirable, as the type is acid in reaction and the best growth of legumes can not be secured unless lime is added. The best growth of the other farm crops also often can not be secured without the application of lime. The addition of a phosphate fertilizer is very desirable on this soil, and tests of superphosphate and rock phosphate are urged. A complete commercial fertilizer cannot be recommended for general use at the present time as it does not seem to bring about any greater effects than those occasioned by the phosphates.

THE PRINCETON FIELD

The results secured on the Clinton silt loam on the Princeton Field, Series I, in Scott County are given in table XXI.

Manure increased the crop yields on this soil in nearly every season, especially on the wheat in 1925, on the corn in 1923, 1927 and 1928, and on the clover in 1922 and 1926. The use of lime with the manure increased still further

TABLE XXI. FIELD EXPERIMENT, CLINTON SILT LOAM, SCOTT COUNTY, PRINCETON FIELD, SERIES I

Plot No.	Treatment	1918 Winter Wheat bu. per A. (1)	1919 Corn bu. per A. (2)	1920 Corn bu. per A. (3)	1921 Oats bu. per A.	1922 Clover tons per A. (4)	1923 Corn bu. per A.	1924 Oats bu. per A.	1925 Winter Wheat bu. per A. (5)	1926 Clover tons per A.	1927 Corn bu. per A.	1928 Corn bu. per A.
1	Check	40.7	69.3	61.8	27.7	1.41	54.0	65.8	13.6	0.96	67.8	64.6
2	Manure	37.4	67.6	68.3	28.4	1.93	63.2	64.8	22.6	1.57	79.7	72.7
3	Manure+lime	43.0	68.2	70.6	32.1	2.13	70.2	65.3	27.5	2.06	97.3	74.2
4	Manure+lime+rock phosphate	47.4	67.8	73.5	31.9	2.25	72.5	63.1	32.1	2.08	96.4	76.4
5	Manure+lime+super-phosphate	45.2	64.0	70.8	35.1	2.29	73.2	75.1	31.8	2.31	86.9	79.2
6	Manure+lime+complete commercial fertilizer	37.3	68.4	73.0	36.4	2.34	68.1	71.9	32.4	2.15	89.8	80.7
7	Check	31.7	57.0	57.5	24.4	1.60	53.0	62.2	16.9	0.73	59.7	50.3
8	Crop residues	---	52.6	58.6	29.6	1.47	55.2	66.4	15.5	0.72	57.4	52.2
9	Crop residues+lime	31.7	62.4	67.3	29.7	2.14	61.8	65.6	23.8	1.35	78.4	66.6
10	Crop residues+lime+rock phosphate	35.0	64.1	68.7	29.8	2.28	65.0	63.4	26.7	2.06	81.3	69.8
11	Crop residues+lime+superphosphate	31.7	66.6	61.5	31.1	2.18	68.0	75.1	27.1	2.03	89.0	74.4
12	Crop residues+lime+complete commercial fertilizer	36.2	65.2	69.5	30.8	---	70.1	73.5	28.3	2.25	83.8	74.5
13	Check	28.2	59.3	59.5	25.5	---	58.6	54.4	17.5	0.98	64.0	54.4

(1) Three tons lime applied August, 1917. Yield on plot 8 an error.
(2) Clover poor and plowed up.
(3) Plot 11 many missing hills, low yields.
(4) Yields on plots 13 and 14 lost due to error.
(5) Stand of wheat very thin due to extreme dry spring.

the yields of crops on this soil. The beneficial effects were particularly evidenced on the clover in 1922 and 1926 and on the corn in 1927. Increases in the yields of wheat, corn and oats were also secured in practically every season.

The addition of rock phosphate with the manure and lime increased the yields of crops in most seasons; the gains, however, were generally not large. The superphosphate with the manure and lime considerably increased the yields in several cases. In one or two seasons, however, the effects of the superphosphate were no greater than those brought about by the rock phosphate. The oats in 1924 and the clover in 1926 showed the largest effects from the use of the superphosphate. The complete commercial fertilizer with manure and lime gave somewhat greater effects than the superphosphate in most seasons but in others its beneficial influence was less, and in no case was the difference very greatly in favor of the complete commercial fertilizer.

The crop residues had little effect on the various crops grown, bringing about only slight increases in some seasons. Lime with the residues, noticeably increased the crop yields in most seasons, the largest beneficial effects being shown on the clover in 1922 and in 1926, and on the corn in 1919, 1920, 1923 and 1928.

The rock phosphate with the crop residues and lime increased the crop yields in all but one season. In the case of the clover crop the increases were very definite. On the other crops smaller increases were secured. The superphosphate with the crop residues and lime showed larger effects than the rock phosphate in some seasons. This was particularly true in the case of the oats in 1921 and 1924, and the corn in 1927 and 1928. In several seasons, however, there were smaller effects from the superphosphate than from the rock phosphate. The complete commercial fertilizer gave larger increases than did the rock phosphate and superphosphate in several cases. This was noted particularly on the clover in 1926. In most seasons, however, there was little difference between the effect of that material and that of the phosphates.

These data indicate that the application of manure is particularly desirable on this soil, and that large increases in the yields of general farm crops may be secured from its use. The type is acid in reaction, and the application of lime is very desirable. Legume crops will be benefited particularly by the use of lime, but considerable gains in the yields of other general farm crops will often follow its application. The addition of a phosphate fertilizer would undoubtedly be of value on this type. The data do not definitely indicate whether the superphosphate or rock phosphate should be employed. Tests of the two phosphates under individual farm conditions are very desirable. The use of a complete commercial fertilizer on this soil would not seem to be as profitable as the application of a phosphate.

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

The laboratory, greenhouse and field tests which have been discussed earlier in this report have given some indications of the fertilizer treatments most desirable for use on the soils of this county. A few general recommendations may, therefore, be given for the handling of some of the more important soil types. The suggestions offered are based upon the experiences of many farmers as well as upon the results of experimental work carried out on the main soil types of the county. Only such suggestions are offered as have been found to be of value in practice and any of the recommendations made may be put into effect on any farm.

In connection with the use of some fertilizers, tests on individual farms are suggested. Such tests may be readily carried out and many farmers are already securing very valuable results from tests on their own farms. The results secured in this way not only indicate the value of certain fertilizer materials on the particular farm but they also indicate the results which many other farmers on the same soil type may secure. Directions which may be followed in carrying out farm tests are given in Circular 97 of the Iowa Agricultural Experiment Station.

Liming

The analyses given earlier in this report have shown that all the soil types in the county are acid in reaction. Not only are the surface soils acid, but the acidity extends down thru the lower soil layers. Apparently there is need for the extensive use of lime on these soils. The figures in table IV indicate only roughly the lime requirements of the various soil types. There is such a wide variation in the acidity of the soils and in the need for lime that even soils of the same types from different fields will often show different needs. To determine accurately the need for lime in any area, the soil from that area should be tested. Only in this way will it be possible to apply the proper amount of lime. Farmers may test their own soils for acidity or lime requirement but it will usually be more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station where it will be tested free of charge.

In general the most satisfactory yields of crops are not secured on acid soils. Corn and small grain crops are less sensitive to acidity than are the legumes, but even grain crops will frequently be greatly benefited by applications of lime to the soil when it is acid. With legumes such as sweet clover, alfalfa and red clover, the crop may fail on acid soils, and the beneficial effects of liming may be very great. It is important, therefore, that lime be applied to acid soils in the amounts shown to be necessary according to the tests, if the yields of general farm crops and particularly of legumes are to prove satisfactory.

In the experiments discussed earlier in this report, large crop increases were secured from the application of lime to some of the more extensively developed types of the county. Beneficial effects were shown on the Carrington loam, the Carrington silt loam, the Clyde silt loam, the Tama silt loam and the Clinton silt loam. Other soil types in the county would also undoubtedly be benefited to a large extent by the use of lime. Numerous tests and the practical experiences of many farmers have indicated the value of lime on the acid soils in this county.

For the continued fertility of the soil, it is important that lime be applied regularly. One application of lime will not be sufficient for an indefinite period. Soils should be tested for acidity and lime needs at least once in a rotation, preferably preceding the growing of the legume crop. The lime may then be applied where it is most needed and where it will bring about the greatest effect. The influence of the lime will often be evident, however, on the succeeding grain crops as well as on the legume crops of the rotation.

Further information regarding the use of lime, losses by leaching and other points connected with liming will be found in Extension Service Bulletin 105, of the Iowa Agricultural Extension Service.

Manuring

Many Delaware County soils are rather poorly supplied with organic matter, as is indicated by their light color and low crop producing power. On the more extensively developed upland soils, which are darker in color and gently undulating in topography, crop yields are more satisfactory and the color of the soils is darker, indicating a higher content of organic matter. On the light colored phase of the Tama silt loam, on the Clinton silt loam, and on the Carrington, Lindley and Shelby sandy loams the need for organic matter is very evident. The Carrington loam, the Carrington silt loam and the typical Tama silt loam are much better supplied. The Clyde silt loam is high in organic matter. Even on the latter types, however, there is need for the application of organic matter at regular intervals, if the supply of this constituent is to be kept up. On the lighter colored soils fertilizing materials supplying organic matter are very desirable for use at the present time.

The most desirable method of increasing and maintaining the supply of organic matter in soils is by the proper preservation and application of all the farm manure produced. On the livestock farms manure, if properly used, will aid materially in maintaining the fertility of the soil. It brings about large increases in the yields of general farm crops. The experiments reported earlier have shown the large effects of this material on the Carrington loam, the Carrington silt loam, the Clyde silt loam, the Tama silt loam and the Clinton silt loam. Not only are the lighter colored poorer soils benefited, but the manure has a pronounced effect on the richer, blacker soils like the Clyde and Tama types. Many of the other types in the county, particularly those which are light in color and sandy in texture, would show as great or even greater effects from the addition of manure. The liberal application of farm manure to all the soils of this county is strongly recommended, if the best crop yields are to be secured and if the land is to be kept permanently productive.

The proper utilization of all crop residues also aids in maintaining the supply of organic matter in the soil. Under the livestock system of farming, the residues are used for feed or bedding and are then returned to the land with the manure. Under the grain system of farming, the residues are stored and frequently allowed to decompose partially before being applied, or they may be applied directly to the land. Under both types of farming, the residues should all be returned to the soil because of their fertility value.

On most livestock farms the supply of manure is inadequate to permit of additions to all the soils at regular intervals. On grain farms little or no manure is produced and some other means must be resorted to, if the supply of organic matter is to be kept up. On all grain farms, therefore, and on practically all livestock farms, the use of leguminous crops as green manures is very necessary to aid in supplying organic matter. Inoculated legumes have a double value when used as green manure, for they not only supply organic matter to the land but also add the nitrogen which they have taken from the atmosphere. Green manuring may be practiced with large profit on many of the soils of Delaware County at the present time. On the lighter-colored, coarser-textured types, the beneficial effects will be particularly great, but crop yields may be increased materially on all the soils of the county. The practice of green manuring should not be followed carelessly, however, as undesirable results may occur if the material is not properly decomposed in the soil. Farmers in this county should see to it that the supply of organic matter in their soils is kept up by the proper use of manure, green manures and crop residues.

The Use of Commercial Fertilizers

The phosphorus content of Delaware County soils is quite low, and it is apparent that the supply of this necessary plant food constituent is insufficient for the best crop growth over any long period of years. Certainly the use of a phosphate fertilizer will be needed on these soils very soon and it seems probable that the application of some phosphorus carrier might be of large value at the present time.

Rock phosphate and superphosphate are the two materials which may be utilized to supply phosphorus to the land. The superphosphate is more expensive but is applied at a much lower rate, the usual application being 150 pounds per acre annually or three years out of four in the four-year rotation.

The rock phosphate is applied at the rate of 1,000 to 2,000 pounds per acre once in four years. The former supplies the element phosphorus in a form which is readily available for plant use, while in the rock phosphate the phosphorus is unavailable and must be changed into an available form before it will have any value. Frequently rock phosphate does not show its largest effect until the second year after application.

It has been shown in the experiments discussed earlier in this report that one or the other of these phosphate fertilizers may be used with profit on the more extensively developed types in Delaware County. In some cases the superphosphate proved preferable but in other instances the rock phosphate gave quite as profitable returns. It is impossible, at the present time, to draw definite conclusions regarding the relative value of these two materials on the soils of this county. Farmers are urged to test both phosphates on their own soils and thus to determine for their particular conditions which material may be used the more profitably. Simple tests along this line may be carried out quite readily on any farm.

The lighter colored, coarser textured types in Delaware County are not well supplied with nitrogen and applications of some fertilizing material supplying this element are desirable at the present time. None of the types, however, are so well supplied with nitrogen that the element may be overlooked when systems of permanent fertility are planned. There is a constant removal of nitrogen from the soil by the growth of crops and by washing out in the drainage waters, and hence the supply gradually decreases. Even if there is sufficient present, therefore, to meet the needs of crops at the present time, some fertilizing material containing nitrogen must be applied regularly or the amount of this constituent will soon become inadequate for the best crop yields. On all the soils of the county, then, it is important that fertilizing materials supplying nitrogen be used regularly, and in the case of the lighter colored types, the application of such materials is very necessary now.

The application of farm manure to the land will aid in maintaining the content of nitrogen in the soil and the utilization of all crop residues will also prove of value. The cheapest and best method, however, of increasing the nitrogen content of soils is to use leguminous crops as green manures. When well inoculated, legumes take a large part of their nitrogen from the atmosphere and hence when turned under in the soil there is usually a large increase in the content of nitrogen. Green manures add nitrogen, but they are also of value in that they supply organic matter to the soil. Green manuring is of especially large value on the light-colored, coarse-textured types in the county but is also worth while on the darker colored soils. Thru proper growing and handling of legume crops for green manuring purposes, the nitrogen content of the soil may be increased and kept up without the use of expensive commercial nitrogenous fertilizers. The latter cannot be recommended for general use in the county at the present time. For truck crops and garden crops, they may be used with profit, but in all cases such fertilizers should not be extensively applied until tests have been carried out on small areas and the value of the materials definitely shown.

Most of the soils in the county are well supplied with potassium, and the use of commercial potassium fertilizers is probably unnecessary at the present time. If the soil is kept in the best condition from the standpoint of drainage and cultivation, supply of organic matter, reaction and plant food supply, the production of available potassium, thru the action of microorganisms, will usually be adequate for crop needs. For general farm crops the addition of commercial potassium fertilizers should not be made to large areas until tests have been carried out on small areas and the value of the application proven. If the fertilizer gives profitable effects, there is no objection to its application. For special crops, such as truck or garden crops, the use of a potassium fertilizer may be of large value now.

Complete commercial fertilizers are probably of less value on the soils of this county at the present time than phosphates. The tests given earlier in this report have not indicated any large increases in crop yields from the use of complete fertilizers over those secured from the use of superphosphate. Complete fertilizers are more expensive than superphosphate and hence they must have a much larger effect on crop yields to prove profitable. For general farm crops a phosphorus fertilizer would probably prove more desirable. For special crops, such as truck crops, special brands of complete fertilizers may be distinctly profitable for use. In all cases, however, whether general crops or truck crops are concerned, tests of complete fertilizers in comparison with superphosphate are very desirable before applications are made to extensive areas. If the complete fertilizer proves more profitable, then its application may be made with the assurance of profit. There is no objection to the use of complete commercial fertilizers, it is merely a question of profit.

Drainage

The natural drainage system of the county, as noted previously in this report, is fairly well developed. On the loessial upland sections drainage is usually adequate. Here the various streams with their tributaries and the intermittent drainageways extend into practically all parts of the upland. In the drift section, however, there are a number of areas where drainage is rather poorly developed. In many of the more level drift uplands there are poorly drained depressions at the heads of drainageways and near the smaller streams. Occasionally the subsoils are heavy and impervious, and the drainage of the types is restricted. The Clyde silt loam on the drift uplands is usually poorly drained and there are areas in some of the other types in which drainage is inadequate. On the terraces the Bremer soils are poorly drained, and on the bottomlands the Wabash types are in need of drainage. The latter soils should also be protected from overflow, if they are to be satisfactorily productive.

Wherever a soil is too wet, crop yields will not be entirely satisfactory. The first treatment needed on the soil types mentioned above is the installation of tile in order to permit of adequate drainage. The expense of tiling may be considerable but the increased crop yields secured will soon pay for the installation. No fertilizing material will prove of any large value on soils which are not properly drained. For maximum crop yields and continued fertility, adequate drainage of the soils should always be carefully provided.

The Rotation of Crops

The continuous growing of one crop will quickly reduce the fertility of the soil. This has been conclusively demonstrated in many experiments and in the experiences of many farmers. Where continuous cropping is practiced, the yields gradually decrease and sooner or later they become so low that the crop proves unprofitable. In spite of the general knowledge of this fact, however, the large money value of some crops often induces farmers to follow a system of continuous cropping.

Data have been secured which indicate definitely that the rotation of crops is a much more profitable practice than continuous cropping even tho crops of lower money value are included in the rotation. This is due to the fact that under a rotation system, crop yields are not decreased as rapidly as when one crop is grown continuously. Furthermore, under a rotation system, it is much easier to maintain the fertility of the soil.

No special rotation experiments have been carried out in Delaware County but some general recommendations may be given regarding rotations which will probably prove of value. From among those listed here, some one may be chosen for use or to serve as a basis upon which a rotation may be worked out for any individual farm conditions.

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 rotation)

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 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 clover)
Third year—Clover

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 could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land" and the cropping of the soil are the factors which determine the occurrence of this injurious action.

The two types of erosion are 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 is less harmful and 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 occurs to a considerable extent in some of the soils of Delaware County. In the drift uplands the Lindley and Shelby soils are subject to extensive washing, and even some areas of the Carrington loam are injured to some extent. On the loessial uplands the Clinton silt loam and particularly the steep phase of this type are frequently badly eroded. Wherever erosion occurs, some means to prevent or control it 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 customary to "plow in" the small gullies that result from 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"—This method requires less work and there is less danger of washing out. The process consists of 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 3 or 4 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, thus 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 are 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. A number of methods may be used to fill small gullies but it is not practicable to fill them with soil; too much work is involved and the effect 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, staking it down with posts. 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 satisfactorily control erosion under some conditions. In general, however, 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 long line of tile down the gully and beneath the dam. An elbow or a "T," called the surface inlet, usually extends 2 or 3 feet above the bottom of the gully. A large tile should be used in order to provide for flood waters, and the dam should be provided with a concrete 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 the dam, such as sorghum, or even oats or rye, later seeding 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 are plentiful, 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 as well, and for quick results thickly planted sorghum may be employed.

The Concrete Dam—One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Owing to their high cost and to the difficulty involved in securing correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage—The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil and thus decreases the tendency toward erosion.

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, especially where such lowlying areas are crossed by small streams, and the land may be badly cut up and rendered almost 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 trees, such 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 of value in preventing the injurious washing and which also aid 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 cornstalks 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 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 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 DELAWARE COUNTY*

There are 24 soil types in Delaware County and these with the light colored phase of the Tama silt loam, the steep phase of the Clinton silt loam and the area of peat, make a total of 27 soil areas. These are divided into five large groups according to their origin and location. The groups are drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils.

Drift Soils

There are eight drift soils in the county, classified in the Carrington, Clyde, Lindley, Shelby and Thurston series. Together they cover 58.2 percent of the total area.

CARRINGTON LOAM (1)

The Carrington loam is the most extensively developed drift soil and the largest individual soil type. It covers 22.9 percent of the total area. It is extensively developed on the uplands in all but the northeastern part of the county, and there are many large individual areas of the type in Adams, Prairie, Coffins Grove, Richland, Honey Creek, Delaware, Milo, Hazel Green, Union, Delhi, Oneida, South Fork and North Fork Townships. It is closely associated with the Carrington silt loam, which is likewise found in extensive areas on the uplands, with the Carrington sandy loam and with the Clyde silt loam in the depressions and along the intermittent drainage lines. In the northwestern corner of the county it is associated with the Lindley sandy loam and the light colored phase Tama silt loam, and in the southeastern part it is separated from the terraces and bottomlands along the Maquoketa River by large areas of the Clinton silt loam and the steep areas of this type.

The surface soil of the Carrington loam consists of a dark brown friable loam, extending to a depth of 12 to 16 inches. The subsurface soil is a light grayish-brown loam which at 18 to 20 inches becomes a yellowish-brown compact loam or clay loam. In the lower subsoil the color is a lighter yellowish-brown and the soil is sometimes less friable. There are many small stones and gravel thruout the soil section, and boulders sometimes occur on the surface.

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

There are a number of variations from the typical soil. In places the surface soil contains considerable medium and fine sand. In many areas the subsoil at 30 to 36 inches is a sandy or gravelly material, resembling the Shelby subsoil. Where the type occurs in level areas and in depressions, the surface soil is darker and more silty in texture, the subsoil is less friable and often shows mottlings of yellow and gray. This latter variation represents a gradation from the typical Carrington to the Clyde silt loam with which the type is so often associated.

In topography the Carrington loam is undulating to rolling. In some areas it occurs on steep slopes and considerable erosion occurs. The natural drainage of the type is good.

Nearly 90 percent of the soil is under cultivation, corn, oats and hay being the chief crops. Corn yields 40 to 45 bushels per acre on the average, altho frequently yields of 60 and 70 bushels per acre are secured. Oats yield 35 to 40 bushels per acre and clover hay 1 to 2 tons per acre. Barley, wheat, rape, millet and a few other minor crops are occasionally grown.

The chief needs of the Carrington loam to make it more productive are for organic matter, lime and a phosphate fertilizer. Liberal applications of farm manure are of value on this type and bring about large increases in crop yields. The use of a legume as a green manure would also be of value on this soil. The soil is acid in reaction and additions of lime are very necessary, especially for legume crops. The use of a phosphate would undoubtedly be of value, and tests of rock phosphate and superphosphate are urged. The greenhouse and field tests discussed earlier in this report have indicated the beneficial effects of these treatments on the yields of general farm crops on this soil.

CARRINGTON SILT LOAM (83)

The Carrington silt loam is the second largest drift soil and the third largest type. It covers 12.4 percent of the total area. It occurs in extensive areas in the southern part of the county and in many smaller areas in association with the Carrington loam in other parts of the area. The Carrington silt loam is most extensively developed in Adams, Prairie and Hazel Green Townships.

The surface soil of the Carrington silt loam is a dark-brown to nearly black friable silt loam, extending to a depth of 10 to 14 inches. Below this point the soil is a grayish-brown or dull brown, fairly compact silt loam and at 20 to 24 inches, the subsoil is a light brown or yellowish-brown silty or gritty loam or silty clay loam, continuing to a depth of 36 inches or more. The lower subsoil is usually rather plastic when wet but it is crumbly when dry. In some areas, the lower subsoil is more or less sandy and some stones and gravel occur but to a less extent than in the Carrington loam. Where the type adjoins the Carrington loam the boundary lines are often rather arbitrarily placed, as there is a gradual transition from one type to the other.

In topography the Carrington silt loam is smooth to undulating, sloping or gently rolling. Drainage of the type is excellent. It is practically all under cultivation and general farm crops are grown. The yields are very similar to those secured on the Carrington loam.

The needs of this type to make it more productive are for farm manure, lime and a phosphate fertilizer. The addition of liberal amounts of farm manure or the turning under of a legume as a green manure would be of large value. The type is acid in reaction and lime is needed, especially for legume crops. A phosphate, either rock phosphate or superphosphate, is strongly recommended for use.

CLYDE SILT LOAM (84)

The Clyde silt loam is the third drift soil in area and the fifth most extensively developed type. It covers 9.6 percent of the total area. It occurs in many areas thruout the drift section of the county, being developed in narrow strips along the minor drainageways and extending up the adjacent slopes. It occurs also in the intermittent drainageways and in sags and depressions in the uplands. There are no large individual areas of the type, but the total acreage in the county is considerable.

The surface soil of the Clyde silt loam is a black friable silt loam, extending to a depth of 8 to 12 inches. At this point there is a dark grayish-brown or nearly black compact, slightly plastic silt loam or silty clay loam which becomes mottled with yellow-brown and gray at 20 to 22 inches and more mottled and plastic at lower depths.

In some places the lower 6 or 8 inches of the three-foot section consist of a yellowish-gray to bluish-gray plastic clay more or less mottled and stained with brown, rusty brown and gray. Occasionally the lower subsoil contains sand or gravel or both in considerable amounts. Boulders occur frequently on the surface and thru the soil section. When the type occurs adjacent to sandy soils, the surface soil is usually somewhat sandy, approaching a loam in texture. Along some of the minor streams, some alluvial material is undoubtedly included with the type. Where it adjoins the O'Neill loam, the boundary lines between the types are drawn rather arbitrarily, as there is a gradual transition from one type to the other.

In topography the Clyde silt loam is flat to depressed, and natural drainage is poor. In some of the more poorly drained areas the surface of the soil is hummocky and boggy.

When undrained, areas of this soil are used mainly for pasture or hay; when well drained, general farm crops are successfully grown. About 30 percent of the type was sufficiently drained in 1922, so that crop growth was satisfactory. Corn yields 45 to 60 bushels per acre. Hay yields 2 to 3 tons per acre. Small grains grow well but tend to lodge.

This soil needs drainage, primarily, to make it more productive. When drained, the addition of a small amount of farm manure would be desirable to stimulate the production of available plant food. The type is acid, and lime is needed, especially if legumes are to be grown. The use of a phosphate fertilizer would also undoubtedly prove of value, and tests of rock phosphate or superphosphate are recommended.

CARRINGTON SANDY LOAM (3)

The Carrington sandy loam is the fourth largest drift soil and the sixth type in area. It covers 7.7 percent of the total area. It occurs mainly in a belt several miles in width extending from the northwest to the southeast across the county. The largest individual area is located southeast of Edgewood, covering an area of about 5 square miles. Other rather extensive areas of the type occur in the central part of Coffins Grove Township, east of Dundee, around Milheim and southwest and southeast of Delaware. Numerous small areas of the type occur thruout the entire drift section of the county.

The surface soil of the Carrington sandy loam is a dark brown friable sandy loam, extending to a depth of 12 to 16 inches. Below this point is a lighter brown sandy loam which at 22 to 24 inches becomes a somewhat heavier, light brown sandy loam or heavy sandy loam.

In some areas the surface soil is lighter in color than typical, approaching a grayish-brown to dull brown sandy loam or loamy sand which at 10 to 12 inches grades into a yellowish-brown loamy sand, becoming a lighter yellowish in color at the lower depths. In the flatter areas mottling or staining occurs in the lower part of the three-foot section. Normally the lower part of the three-foot section is somewhat gravelly but not enough to make the soil drouthy.

On some of the more exposed locations or on ridges or knolls the soil has been drifted by the action of wind, and in places "sand blows" or "blow-outs" have been formed. These areas are of small extent and have been included with the type. The two most important areas of this sandy soil occur about one mile northeast of Earlville and about one-half mile east of Thorpe. In small depressions and along some drainageways small areas of a rather heavy soil resembling the Clyde types are included with this soil.

In topography the type is slightly to strongly rolling. Drainage is generally adequate, except in small depressions and along a few drainageways.

About 70 to 75 percent of the area is utilized for cultivated crops, the remainder being in pasture. Along some of the larger streams there are narrow forested areas. Corn is the chief crop, yielding 30 to 35 bushels per acre. Oats yield about 35 bushels per acre and timothy and clover hay 1 to 1½ tons per acre.

The chief need of this soil is for organic matter. Liberal amounts of farm manure always bring about large increases in crop yields. The turning under of legumes as green manures would also be of large value. The type is acid, and lime should be applied for the best crop yields, particularly of legumes. The addition of a phosphate fertilizer would undoubtedly be profitable, and tests of rock phosphate and superphosphate are strongly recommended.

LINDLEY SANDY LOAM (161)

The Lindley sandy loam is the fifth largest drift soil, covering 3.2 percent of the total area. It occurs in a number of areas of considerable size, chiefly in the vicinity of the Maquoketa River. The largest areas are found in the northwestern part of the county in Richland Township, west of Forestville, south of Earlville, near Plum Creek, north of Hopkinton and south and east of Delhi. Other small areas occur in various parts of the territory adjacent to the Maquoketa River.

The surface soil of the Lindley sandy loam is a loose grayish-brown sandy loam or loamy sand to a depth of 12 to 15 inches. At this point there is a yellowish-brown loamy sand which varies somewhat in coarseness and continues downward to 3 feet or more. Below 24 to 28 inches the subsoil varies somewhat, in places being a loose sand or gravelly material and in other areas a sticky yellowish sandy loam. On the higher locations the surface soil is sandy and loose and is subject to movement by high winds when the soil is in cultivated crops or bare. A few outcrops of rock of small extent are included with this type. In topography the soil varies from gently rolling to rolling and is somewhat rugged or broken near the streams. Drainage is thoro, and the soil is apt to be rather drouthy.

Originally the Lindley sandy loam was forested mainly with red, bur and white oak. About 60 percent of the type is now under cultivation, the remainder being used for timber or pasture or both. Corn, oats, timothy and clover are the chief crops. Corn yields 25 to 40 bushels per acre, oats 25 to 35 bushels and hay 1 to 1½ tons per acre. Some watermelons and other vegetables and truck crops are grown on this soil.

The chief need of this type is for the incorporation of organic matter. Liberal additions of farm manure are very desirable, and the turning under of leguminous crops as green manure would be of large value. The type is acid in reaction, and additions of lime are very necessary, especially for legumes. The use of a phosphate fertilizer would be of value, and tests of superphosphate are recommended. For truck crops the use of a commercial fertilizer would undoubtedly be of value, and tests of those designed for special crops on sandy soils are urged.

SHELBY SANDY LOAM (221)

The Shelby sandy loam is a minor type, covering 2.1 percent of the total area. It occurs in the southeastern part of the county, chiefly in North Fork and South Fork Townships. The largest developments of the type are west of Rockville, between the North Fork of the Maquoketa River and Plum Creek and in the vicinity of Sand Springs and Hopkinton.

The surface soil of the Shelby sandy loam is a dark brown to grayish-brown sandy loam, extending to a depth of 10 to 14 inches. Below that point is a heavier sandy loam, light brown in color. At 28 to 30 inches there is a layer of a more sandy and looser material, sometimes gravelly, varying from a light brown to a yellowish-brown in color and continuing to a depth of 36 to 48 inches or more. In the area a mile southeast of Rockville, there is a much sandier variation of the type. Here the soil is a dark grayish-brown loamy sand, grading at 8 to 16 inches into a loose light brown or yellowish loamy sand to a depth of 36 inches or more. In topography this soil is rolling, drainage is excessive and the soil is drouthy in dry seasons.

Originally some of this soil was forested, and scattering growths of oaks still remain. About 60 percent of the type is under cultivation. In the better areas the yields are very much the same as on the Carrington sandy loam, but in the more sandy areas the yields are lower and in dry seasons, crops are poor. The chief need of this soil is for organic matter. Liberal applications of farm manure are very desirable. Large increases in crop yields will follow the application of manure. The use of a leguminous crop as a green manure will also be of value in building up the supply of organic matter and reducing the injury to crops in dry seasons. The type is acid in reaction, and the addition of lime is very necessary. The use of lime is particularly desirable where legume crops are to be grown. The addition of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended.

CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor type, covering only 0.2 percent of the area. It occurs mainly in a few very small scattered tracts, usually in association with the Carrington sandy loam or the Carrington loam. The largest area is about one-half square mile in extent and is found southeast of Rocky Ridge School in Sections 35 and 36 of Hawkins Grove Township.

The surface soil of the Carrington fine sandy loam is a dark brown or dark grayish-brown fine sandy loam, extending to a depth of 10 to 12 inches. Below this point the subsoil gradually becomes lighter in color and consists of a more compact fine sandy loam, grading into a light brown to yellowish-brown fine sandy loam. In some areas the lower part of the three-foot section is a loamy fine sand. In topography the type is rolling to undulating and drainage is good to excessive.

About 80 to 85 percent of the type is under cultivation, and general farm crops are grown. The yields are somewhat lower than those secured on the Carrington loam but are very similar to those obtained on the Carrington sandy loam. The type is chiefly in need of organic matter to be made more productive, and the turning under of leguminous crops as green manures would be of large value. The liberal addition of farm manure would improve crop yields materially. The type is acid in reaction, and additions of lime are very necessary, especially for legume crops. The addition of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended.

THURSTON SANDY LOAM (162)

The Thurston sandy loam is a very minor type, covering only 0.1 percent of the total area. It occurs in a number of small isolated areas in the drift section of the county in association with the Carrington loam on the uplands. There are a number of small areas west of Manchester, in the western sections of Prairie Township and in other parts of the drift region.

The surface soil of the Thurston sandy loam is a brown to dark brown loam or gritty loam, extending to a depth of 10 inches. At this point there is a lighter colored material of about the same texture which at 14 to 18 inches grades into a yellowish-brown sand and fine gravel. In topography the type is rolling to strongly rolling, occurring on knolls and knobs or small elevations in the drift uplands. Drainage is good to excessive, and in dry seasons the soil is drouthy.

Only a small part of the type is cultivated, and crop yields are low, owing to the drouthy nature of the soil. The chief need of the type is for organic matter. The application of farm manure would be of very large value, and the turning under of a leguminous crop as a green manure would improve the moisture holding power and make the soil more productive. The type is acid and in need of lime, especially for the growth of legumes. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended.

Loess Soils

There are six loess types in the county, classified in the Tama, Clinton, Dodgeville and Fayette series, and these with the light-colored phase of the Tama silt loam and the steep phase of the Clinton silt loam, make a total of eight loess soils. Together they cover 29.7 percent of the total area.

TAMA SILT LOAM (120)

The Tama silt loam is the most extensive loess type and the second largest soil in the county. Together with the light colored phase, which is much more limited in extent, it covers 14.9 percent of the total area. It is largely developed in the northeastern townships, the largest area covering a large part of Colony and Bremen Townships and portions of Elk, Oneida and Honey Creek Townships. Smaller areas of the type are found in Delhi Township east and south of Delhi, in South Fork Township and in Hazel Grove and Union townships.

The surface soil of the Tama silt loam is a dark brown to nearly black, friable, even-textured silt loam, extending to a depth of 12 to 14 inches. At this point there is a layer about 3 or 4 inches in thickness of a dull brown silt loam which grades into a compact light brown silt loam. At lower depths the subsoil becomes slightly lighter colored, continuing compact but friable in structure. In some of the flatter areas and in slight depressions the subsoil below 28 to 30 inches is less friable, approaching a silty clay loam in texture, and is mottled with light gray and yellowish-brown. On the more rolling areas the surface soil is somewhat shallower, but along the lower slopes the surface soil is frequently 18 to 20 inches in depth. In topography the type is gently rolling to undulating. Drainage is good.

Practically all of the soil is now under cultivation, and general farm crops are grown. The yields of corn average above 50 bushels per acre, and frequently yields as high as 75 to 80 bushels per acre are secured. Oats average 45 to 50 bushels per acre. Where wheat, barley and rye are grown, profitable yields are secured. Timothy and clover yield from 1 to 2 tons per acre. Clover alone yields as high as 2½ tons per acre. Sorghum, millet and rape are sometimes grown.

The Tama silt loam is naturally a productive soil, and yields of general farm crops are ordinarily quite satisfactory. It will respond, however, to certain soil treatments. The application of manure is very desirable on the type, and increases in crop yields will follow its use. The soil is acid in reaction, and the application of lime is very desirable for general farm crops and particularly for legumes. The use of a phosphate fertilizer would undoubtedly be of value and tests of superphosphate and rock phosphate are recommended. The experiments discussed earlier in this report have indicated the large value of applications of farm manure, lime and a phosphate fertilizer on this soil.

TAMA SILT LOAM (LIGHT-COLORED PHASE) (177)

This is a minor type, covering about 1 percent of the total area. It occurs in a number of areas, most of which are limited in extent. The largest area of the type is found in the southwestern part of the county in western Honey Creek Township, extending over into Richland Township. Other areas occur in Bremen Township in the eastern part of the county and in Delhi Township, northeast of Delhi.

The surface soil of the light-colored phase Tama silt loam is a dark grayish-brown or grayish-brown friable silt loam, usually extending to a depth of about 12 inches. It is very similar to the surface soil of the typical Tama except for the shallower depth of the surface layer. Below 12 inches there is a light grayish-brown silt loam, passing at 18 or 20 inches into a light brown, compact but friable silt loam. It continues compact and becomes a little lighter colored at the lower depths. In some areas the soil is somewhat lighter in color and shallower in depth, especially where the topography is more strongly rolling. It usually occurs near areas of the typical Tama, separating this type from the areas of Clinton silt loam, and frequently the boundary lines between the types are placed more or less arbitrarily. There is a gradual transition from one soil to the other.

About 90 percent of the soil is under cultivation, and general farm crops are grown. Yields are similar to those secured on the Tama silt loam altho they tend to be somewhat lower. The needs of the soil are very much the same as those mentioned for the typical Tama. Owing to the lighter color of the soil and to the shallower surface layer, there is a slightly greater need for additions of organic matter. The use of farm manure and the turning under of leguminous crops as green manures would be of especially large value. The use of lime is necessary, and additions of phosphate fertilizers would undoubtedly be of value.

CLINTON SILT LOAM (80)

The Clinton silt loam is the second largest loess type and the fourth most extensively developed soil. With the steep phase, which is much smaller in extent, it covers 11.9 percent of the total area. It is most extensively developed in the northeastern part of the county in Colony and Elk Townships. There are, however, large areas of the type in the southeastern townships south of Delhi, extending to the Jones County line; north of Hopkinton; in South Fork and North Fork Townships; and in the extreme northwestern corner of the county in Richland Township, north of Forestville.

The surface soil of the Clinton silt loam is a light grayish-brown to light brown, smooth, friable silt loam, extending to a depth of about 8 inches. The subsoil is a light brown or yellowish-brown less friable and more compact silt loam which at 18 to 20 inches grades into a compact silt loam or silty clay loam. In some areas which have been under cultivation for a longer time the surface soil has a light ashy appearance when dry. In uncleared areas the surface layer of 2 or 3 inches is darker than the typical soil, owing to the accumulation of leaf mold.

In topography the Clinton silt loam is rolling to strongly rolling. It occurs on the tops of higher ridges and gentle slopes. Most of the ridge tops are rather narrow. In a few places there are funnel shaped depressions 6 to 12 feet in depth and 12 to 30 or more feet in diameter. Typical examples of this may be seen in the east half of Section I of Colony Township. The drainage of the type is adequate and the soil is subject to erosion.

Practically all of the type was originally forested with oak, elm, walnut and cherry. Probably 60 percent or more is cleared and used for general farm crops. Corn is grown most extensively and yields average 40 to 50 bushels per acre. Oats yield 35 to 40 bushels per acre. Timothy and clover yield 1½ to 2 tons per acre. Excellent pastures are maintained on some areas of the soil.

This type will respond in a very large way to farm manure, and liberal additions are recommended. The turning under of a leguminous crop as a green manure would also be of large value in increasing crop yields. The soil is acid in reaction, and additions of lime are necessary. The use of a phosphate fertilizer would undoubtedly be of value and tests of superphosphate are urged. The experiments discussed earlier in this report have indicated the large effects on yields of general farm crops from applications of manure, lime and a phosphate fertilizer.

CLINTON SILT LOAM (STEEP PHASE) (176)

The steep phase of the Clinton silt loam is a minor type, covering about 2 percent of the total area. It occurs in numerous areas in association with the typical soil, being found on the steeper areas within the type. It occurs on the slopes to the stream valleys and on the more or less deeply eroded areas along the ravines. Along many of the valleys the slopes are rugged to precipitous, and limestone outcrops frequently are seen.

The surface soil of this phase of the Clinton silt loam is usually a light brown rather than a grayish-brown which is the characteristic color of the typical soil. Owing to the extensive erosion which takes place, the surface layer is much thinner than in the typical areas of the Clinton silt loam. Along the lower slopes the surface soil is somewhat darker. As has been indicated in the type name, the topography of this soil is strongly rolling to steep, rough or broken.

At least 75 or 80 percent of the soil is in forest or permanent pasture. Most of the area is too steep for cultivated crops. Even in the cultivated areas much erosion and serious washing of the surface soil occurs, and gullies are frequently formed.

In the cultivated sections the chief need of the type is for protection from the destructive action of erosion. The incorporation of organic matter would aid in increasing the water holding capacity of the soil and improving its fertility. The use of farm manures and the turning under of leguminous crops as green manures would be of large value. The addition of lime is necessary, especially for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended. From among the methods which are suggested earlier in this report, some one should be chosen to prevent or control erosion before areas of this soil are brought under cultivation.

DODGEVILLE SANDY LOAM (222)

The Dodgeville sandy loam is a minor type, covering 1.5 percent of the total area. It occurs in many small areas, chiefly in the central and southeastern townships. The largest developments of the type are found in Oneida, Delaware, Milo and Delhi townships. There are also a number of areas in North Fork and South Fork Townships, Union Township and Coffins Grove Township.

It is found in association with the Carrington sandy loam or within areas of the Carrington loam and is developed on slopes, in draws and along drainage depressions.

The surface soil of the Dodgeville sandy loam is a dark brown friable sandy loam, extending to a depth of 8 to 10 inches. At this point the subsoil is a light brown or yellowish-brown moderately friable gritty loam. It may rest on limestone rock at any depth from 18 to 36 inches. In some areas just above the limestone there is a brown or reddish-brown gritty clay, usually containing fragments of the limerock. Where the soil is more shallow than typical, limestone fragments of varying sizes are found on or near the surface, and in places there are rock outcrops.

Where the topography is level and the surface soil is not too shallow, the type is cultivated. Probably 25 to 30 percent is in cultivation, the remainder being utilized for pasture or timber lands. On the cultivated areas general farm crops, including corn, oats and hay, are grown. The yields of these crops are generally lower than those obtained on the Carrington sandy loam. In cultivated areas the soil will respond to applications of organic matter, and the use of farm manure and leguminous green manures would be very desirable. The surface soil is acid in reaction, and additions of lime are necessary for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly be of value.

FAYETTE SILT LOAM (163)

The Fayette silt loam is a minor type, covering only 0.6 percent of the total area. It occurs in small areas in various parts of the county in association with the Clinton or Tama soils, being found on the low ridges adjacent to these types. The largest areas occur north of Dundee, west of Edgewood, northwest of Hopkinton, southeast of Delaware and southeast of Ryan. There are also other small areas of the type..

The surface soil of the Fayette silt loam is a light brown to light grayish-brown, friable, smooth silt loam, extending to a depth of 8 to 10 inches. Sometimes the surface soil contains a little very fine sand. The subsoil is a light brown compact friable silt loam grading at 18 to 20 inches into a silty loam somewhat lighter in color and shallower than on the smoother slopes. In some of these depressions or flatter areas, the subsoil below 24 inches is mottled with light gray, yellow or brown. In topography the type is somewhat rolling or sloping, in many places being steep enough to permit of considerable surface washing in the cultivated areas. Drainage is well established.

Originally the type was forested, very much the same as the Clinton silt loam. Practically all of the wooded land is now cleared, and 85 to 90 percent is under cultivation. General farm crops are grown, and yields are very much the same as those secured on the Clinton silt loam. The type will respond profitably to applications of organic matter, and liberal additions of farm manure are very desirable. The turning under of leguminous crops as green manures would also be of large value. The type is acid and in need of lime, especially for the growth of legumes. The addition of a phosphate fertilizer would undoubtedly prove profitable, and tests of superphosphate are recommended.

DODGEVILLE SILT LOAM (204)

The Dodgeville silt loam is a minor type, covering 0.5 percent of the total area. It occurs in several small, widely scattered tracts within the Carrington and Tama soil areas. The larger areas occur east of Petersburg Station and between Oneida and Almoral.

The surface soil of the Dodgeville silt loam is a dark brown silt loam or silty loam, extending to a depth of 6 inches. At that point it grades into a compact dark brown or dull brown heavy silt loam to silty clay loam which at about 18 inches rests on beds of limestone. In some areas the soil is a little deeper than the typical while in other places there are rock outcrops or the rock is covered by only a few inches of soil. A few patches of sandy loam are included with this type.

Practically all of the type is utilized for pasture purposes. The soil is generally too shallow for the best growth of cultivated crops. It is apt to be drouthy. When cultivated it will respond to additions of farm manure and liberal applications of this material are recommended. The use of a leguminous crop as a green manure would be of value. The surface soil is acid, and lime is necessary if legumes are to be grown. The use of a phosphate fertilizer would undoubtedly prove profitable, and tests of superphosphate are recommended.

CLINTON VERY FINE SANDY LOAM (178)

This is a very minor type, covering only 0.3 percent of the total area. It occurs in a number of small areas, being developed chiefly along the Dubuque County line in North Fork Township, north of Rockville. Other small areas occur northwest of Hopkinton.

The surface soil of the Clinton very fine sandy loam is light brown friable very fine sandy loam, extending to a depth of 10 to 12 inches. Below this point there is a lighter brown compact very fine sandy loam which becomes somewhat heavier in texture at the lower depths, usually changing into a silty clay loam between 30 and 36 inches. In some areas the lower part of the three-foot section is lighter in texture owing to the occurrence of considerable amounts of fine and very fine sand. In the virgin or wooded areas the surface layer of 2 or 3 inches is darker in color owing to an accumulation of leaf mold. In topography the type is rolling to strongly rolling.

Originally the soil was forested but most of it is now cleared and about 60 percent is under cultivation. The common farm crops are grown, but yields are somewhat lower than those secured on the Clinton silt loam. The type is low in organic matter and is inclined to be drouthy.

The chief need of this soil to be made more productive is for the addition of organic matter. Liberal applications of farm manure would greatly improve crop yields. The use of leguminous crops as green manures would be of large value in improving the organic matter content of the soil and its water holding capacity. The type is acid and in need of lime, especially for the best growth of legumes. The addition of a phosphate fertilizer would be of value and tests of superphosphate are recommended. For special crops, and especially for truck crops, the use of a complete commercial fertilizer would undoubtedly bring about profitable crop increases.

Terrace Soils

There are five terrace types in the county, classified in the O'Neill, Waukesha, Bremer and Judson series. Together they cover 5.7 percent of the total area.

O'NEILL LOAM (108)

The O'Neill loam is the largest terrace type, covering 3.4 percent of the total area. It occurs in a number of more or less extensively developed areas in various parts of the county, on the terraces along the streams. The largest area of the type is found just south of Manchester and extending towards Golden. Other areas occur along Prairie Creek west of Manchester and along Honey Creek north of Manchester, along Buck Creek in Hazel Grove Township and along Bear Creek near Dyersville. Numerous other small areas of the type are found.

The surface soil of the O'Neill loam consists of a dark brown to nearly black friable loam, usually containing some medium and coarse sand, extending to a depth of about 12 to 16 inches. At this point there begins a gradual change into a brown compact sticky loam which at about 24 to 28 inches changes into a light brown mixture of sand and small gravel. In some areas the gravelly material in encountered at depths of 10 to 12 inches. In other places it occurs at depths of 36 inches or more. In general the lower subsoil is open and porous but in some places it is somewhat loamy. In a few areas the surface material is a silt loam somewhat darker in color than the typical loam. This is true of the area just west of Robinson. The drainage of the type is thoro, and the soil is apt to be drouthy.

About 80 to 85 percent of the O'Neill loam is in cultivation. Some of it is in forest growth, and a few less desirable areas are kept in permanent pasture. Corn is the chief crop and in favorable seasons yields of 35 to 60 bushels per acre are secured. Oats yield 30 to 40 bushels per acre and hay 1 to 1½ tons per acre.

The chief need of this soil is for the addition of organic matter to increase the water-holding power of the soil. Liberal applications of farm manure and the turning under of leguminous crops as green manure would help materially. The soil is acid in reaction, and additions of lime are necessary for the best crop growth, particularly of legumes. The use of a phosphate fertilizer would undoubtedly prove profitable, and tests of superphosphate are recommended.

O'NEILL SANDY LOAM (126)

This is a minor type covering 1.4 percent of the total area. It occurs in numerous areas, varying widely in size, in various parts of the county. The largest development of the type is in the vicinity of Manchester on the terraces along the Maquoketa River. A second rather extensive area occurs near Almoral Station, north of Earlville along Plum Creek. Numerous other small areas of the type are found.

The surface soil of the O'Neill sandy loam is a dark brown or grayish-brown sandy loam, extending to a depth of 12 to 14 inches. Below that point the subsoil is a brown somewhat more compact sandy loam which, at depths varying from 20 to 28 inches, changes into a loose yellowish-brown sand or gravel. In some areas the lower subsoil is less porous and consists of a medium textured sandy loam or loamy sand. In a few places the surface soil is a fine sandy loam. A few very small areas of the O'Neill loam are included with the type, as they could not be separated on the map.

In topography the O'Neill sandy loam is nearly level but there are a few slight elevations and depressions. It occurs on terraces all above normal overflow. Some of the areas are from 10 to 30 feet above the flood plains and a few are as high as 40 to 50 feet above the stream.

About 75 percent of the O'Neill sandy loam has been brought under cultivation. Some of it still shows a scant growth of timber, mostly oak. General farm crops are grown on the cultivated areas and corn yields 30 to 50 bushels per acre. Oats yield 20 to 40 bushels per acre. Rye is often grown, and some hay is produced. Melons and truck crops are grown to some extent on this type.

This soil's chief need is for organic matter to make it more productive and to reduce the injury to crops in dry seasons. The application of farm manure would be of large value, and the turning under of leguminous green manure crops would be of material help. The type is acid and in need of lime, especially for the best growth of legume crops. The addition of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended. Where truck crops are grown, the use of a complete commercial fertilizer might be profitable, and tests of certain brands particularly designed for the crops to be grown are recommended.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is a minor type, covering only 0.6 percent of the total area. It occurs in a number of small areas in various parts of the county, chiefly along the Maquoketa River between Delhi and Hopkinton. Other small areas of the type are found.

The surface soil of the Waukesha silt loam is a dark brown to black friable silt loam, extending to a depth of 12 to 14 inches. The subsoil is a lighter brown compact silt loam grading into a light brown or slightly yellowish-brown, moderately compact, friable silt loam at about 28 to 30 inches. In some areas the lower subsoil is a little heavier, approaching a silty clay. In some of the slight depressions the lower subsoil is mottled slightly with gray and yellowish-brown and is somewhat less friable. In topography the soil is level to flat and natural drainage is good.

Practically all of the soil is under cultivation, and general farm crops are grown. The yields are very similar to those secured on the Tama silt loam on the uplands. The needs of the soil are very similar to those mentioned in connection with the discussion of the Tama silt loam. The addition of organic matter in the form of farm manure or leguminous green manures would be of considerable value. The application of lime would be very desirable, particularly for legume crops. The use of a phosphate fertilizer would undoubtedly prove of value, and tests of superphosphate and rock phosphate are recommended.

BREMER SILT LOAM (88)

The Bremer silt loam is a minor type, covering only 0.2 percent of the total area. It occurs in a few small areas, mainly in the loessial region of the county. The principal areas are found along Bear Creek southeast of Petersburg.

The surface soil of the Bremer silt loam is a nearly black, fairly friable silt loam, extending to a depth of 12 to 16 inches. At this point it grades into a dark brown or dull brown compact silty clay loam which usually becomes slightly mottled with yellow and yellowish-brown at about 20 inches. At the lower depth the texture is heavier and the soil is more plastic, and at 28 to 30 inches the subsoil is a yellowish-brown plastic clay loam or silty clay mottled with bluish-gray, yellow and brown. In some of the areas the subsoil is more friable and there is less mottling in the subsoil. In topography the type is flat, and the drainage is fair. In depressions, however, along some of the minor drainageways leading from the uplands, drainage is somewhat deficient.

About 75 percent of the type is in cultivation, the remainder being pastured. General farm crops are grown on the cultivated areas, and yields are very similar to those secured on the adjacent uplands when the type is adequately drained. The first need of the soil is for thoro drainage, if it is to be made most satisfactorily productive. Small applications of farm manure would be of value to stimulate the production of available plant food. The use of lime is necessary, especially if legumes are to be grown. The addition of a phosphate fertilizer would be of value, and tests of superphosphate and rock phosphate are recommended.

JUDSON LOAMY SAND (179)

This is a very minor type, covering 0.1 percent of the total area. It occurs only in two small areas south of Rockville, along the Dubuque County line.

The surface soil of the Judson loamy sand consists of a brown to grayish-brown loamy sand or light sandy loam extending to a depth of about 12 inches. At this point it grades into a brown to light brown loamy sand, continuing to a depth below 40 inches. In some of the areas the subsoil at about 30 inches is somewhat more loamy. The type occurs on terraces 10 to 15 feet above the stream bottoms. The topography is slightly undulating or in places billowy. Drainage is thoro, and the soil is inclined to be drouthy.

Practically all of the soil is under cultivation, a very limited area being used for pasture. Corn is the chief crop grown, some small grains, oats and rye being produced also. Yields are low except in very favorable seasons. The type is chiefly in need of additions of organic matter to be made more productive. Liberal applications of farm manure are very desirable, and the turning under of leguminous crops as green manure would be of material help. The use of lime is necessary if legumes are to be grown. The addition of a phosphate fertilizer would undoubtedly prove worth while and tests of superphosphate are recommended.

Swamp and Bottomland Soils

There are four swamp and bottomland types in the county, classified in the Wabash, Cass and Genesee series, and these with the area of Peat make a total of five bottomland soils. Together they cover 6.1 percent of the total area.

WABASH SILT LOAM (26)

The Wabash silt loam is the largest of the bottomland soils, covering 3.3 percent of the total area. It is developed most extensively along the streams in the loessial portion of the county altho there are also considerable areas along various of the streams in the drift section. The largest development of the type is in the northwestern part of the county east of Dundee. Other extensive areas are found along Plum Creek north and south of Earlville. It is also developed along Buck Creek, Bear Creek and Sand Creek to a considerable extent.

The surface soil of the Wabash silt loam is a black friable silt loam, extending to a depth of 14 to 18 inches. Below this point the subsoil is somewhat more compact and slightly plastic. The lower part of the subsoil is usually a silty clay loam or silty clay, dark in color, with a dull bluish cast. Below 20 to 24 inches there are more or less pronounced mottlings of brown, brownish-yellow and some rusty brown concretions. In areas where the adjacent uplands are light in color, the surface soil is generally a grayish-brown underlaid at varying depths by a compact silt loam dark in color.

In topography the Wabash silt loam is level to flat with a slight slope toward the streams. Occasionally the surface is broken by old abandoned stream channels and cut by numerous streams which flow thru it, thus interfering seriously with its use for cultivated crops. Drainage is inclined to be deficient and it is overflowed irregularly. In some areas the land has been improved by a deepening and straightening of the river channels and by opening ditches.

The type was originally forested, mainly with elm, walnut, cottonwood, ash and willow. Except for narrow fringes along the stream channels and scattering groves, the Wabash silt loam is largely cleared and used for pasture. About 10 to 15 percent of the type is under cultivation, and corn, the chief crop, averages 50 to 60 bushels per acre and in favorable seasons as high as 80 to 90 bushels per acre. Small grains are grown to some extent but are likely to lodge. Hay produces well and yields of 2 to 2½ tons per acre are secured.

The type is especially valuable for pasture purposes. When cultivated it needs first of all thoro drainage and protection from overflow, if crop yields are to be uniformly satisfactory. The addition of a small amount of farm manure would be of value in stimulating the production of available plant food. The addition of lime would aid in the satisfactory growth of legume crops. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate and rock phosphate are recommended.

CASS LOAM (18)

The Cass loam is a minor type, covering 1.1 percent of the total area. It is found in numerous areas in various parts of the county, chiefly along the larger streams. It is most extensively developed along Prairie Creek west of Manchester, along Honey Creek north of Manchester and along the Maquoketa River in the vicinity of Hopkinton and south of Dundee. Other small areas of the type occur.

The surface soil of the Cass loam is a dark brown friable fine loam, extending to a depth of about 10 inches. The subsoil is a dull brown compact friable loam becoming slightly lighter in color at the lower depths and grading, at about 24 inches, into a light brown, fairly loose mixture of loamy sand and fine gravel. In most places the lower subsoil consists of a sandy loam and in others of a gravelly loam. In some areas, especially in the narrower strips along the stream channels, the surface soil is rather sandy and somewhat lighter in color than the typical soil. In some of the depressions and in small areas protected from overflow, the surface soil is a silt loam. In topography the type is smooth to level and is subject to overflow, and drainage is adequate to excessive.

The type was originally forested and, while most of it has been cleared, is still used mainly for pasture. Probably about 20 percent of the total area is cultivated, general farm crops being grown. In favorable seasons, when the type is not flooded, corn yields 45 to 60 bushels per acre. Oats do well and the hay crops produce satisfactory yields. Sorghum, millet and sudan grass are sometimes grown.

The chief need of this soil is for protection from overflow. When this is accomplished, additions of farm manure would be of value, and the turning under of leguminous crops as green manure would improve the fertility condition. The addition of lime is desirable especially for the growth of legumes. The application of a phosphate fertilizer would undoubtedly be of value and tests of superphosphate are recommended.

GENESEE FINE SANDY LOAM (117)

The Genesee fine sandy loam is a minor type, covering 0.8 percent of the total area. It is found mainly along the Maquoketa River in narrow strips adjacent to the stream channels.

The surface soil of the Genesee fine sandy loam is a brown to dark brown fine sandy loam, extending to a depth of about 10 inches. At this point there is a light brown or yellowish-brown loamy fine sand or fine sandy loam. The lower part of the three-foot section is generally sandy and in some places it contains compact layers. Near the streams the soil is usually a light brown and the texture is somewhat coarser. In these areas the material is very much like riverwash. The surface of the type is more or less uneven and the soil is subject to overflow. Drainage is adequate.

The type is more or less forested with elm, birch, willow, ash, walnut and other species. Very little is cultivated. It is used principally for pasture purposes, for which it is best suited. If cultivated, it needs to be protected from overflow. Additions of farm manure would be of large value, and the turning under of leguminous green manure crops would improve the productive power of the soil. The addition of lime and the use of a phosphate fertilizer would undoubtedly be of value for general farm crops.

WABASH LOAM (49)

This is a minor type, covering 0.8 percent of the total area. It occurs in a number of small areas in various parts of the county, chiefly along Robinson, Plum, and Elk Creeks. There are a few other areas of the type.

The surface soil of the Wabash loam is a dark brown to nearly black friable loam, extending to a depth of 14 to 18 inches. At that point it grades into a compact dull black or bluish-black loamy clay which becomes somewhat less friable at the lower depths. Below 24 to 28 inches there are mottlings of brown and rusty brown or gray. In some areas the lower subsoil is sandy and resembles the subsoil of the Cass loam. Adjacent to the stream channels the material is variable, being gravelly, sandy and sometimes stony. Many patches of Cass loam too small to separate on the map are included. In the northern part of the county along Elk Creek the soil is rather light colored and more or less variable, especially where the bottomlands are narrow.

In topography the type is level to flat, being slightly undulating in places owing to the occurrence of abandoned stream channels. The areas are subject to overflow. The type is fairly well drained. Practically all is used for pasturage, to which it is well adapted. Probably 1 or 2 percent is all that is utilized for cultivated crops. Yields are very much the same as those secured on the Wabash silt loam.

If cultivated, this soil needs protection from overflow. A small amount of farm manure would be of value to stimulate the production of available plant food. The addition of lime is very desirable, especially for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly be of value.

PEAT (21)

Peat is developed to a limited extent, covering 0.1 percent of the total area. It is found in small areas in various parts of the county, chiefly just east of Almoral Station about three and one-half miles northeast of Masonville. It is usually associated with the Clyde silt loam and occurs in similar depressed areas.

Peat consists of a dark brown to black partly decomposed organic matter derived from an accumulation of the remains of water-loving plants and grasses. Most of it is distinctly fibrous, altho the surface layer may be somewhat decomposed. Most of the areas of peat are from 3 to 4 feet in depth but in places it rests on a substratum of dense silty clay, grayish or dark gray in color. In some areas the subsoil material is calcareous.

The areas of peat are utilized for pasture and a rather coarse wild hay is harvested on them. If peat is to be reclaimed it must be thoroly drained. When this has been accomplished, it should be seeded down, preferably to a mixture of timothy and alsike, and allowed to remain in pasture for several years to permit of the decomposition of the peat. Later it may be used successfully for the growth of cultivated crops. When well decomposed, peat will produce very satisfactory yields of vegetables and truck crops, especially if properly fertilized. Applications of superphosphate at the rate of 200 pounds per acre and muriate of potash at the same rate, may prove of large value for the fertilization of reclaimed areas. Corn will not do well on newly drained peat. Small grains tend to lodge but when the peat has been thoroly decomposed, these crops may be grown successfully if properly fertilized.

Residual Soil

There is one residual soil in the county, the Gasconade loam. It is minor in area, covering only 0.3 percent of the total area.

GASCONADE LOAM (184)

This soil occurs chiefly in the eastern part of the county, in the vicinity of Dyersville and in other areas along the slopes leading to the larger streams. The surface soil consists of a dark brown to grayish-brown gritty loam, extending to a depth of only a few inches. Below this point the limestone bedrock is encountered. The soil usually contains fragments of limestone of various sizes.

Practically none of the type is cultivated and is utilized entirely for pasture purposes and some of it is in forest, which is mostly a scrub oak. In many places the limestone rock has been quarried for building purposes or for agricultural use. Owing to the shallow nature of the surface soil, the type is not suited for cultivated crops.

APPENDIX

THE SOIL SURVEY OF IOWA

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

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

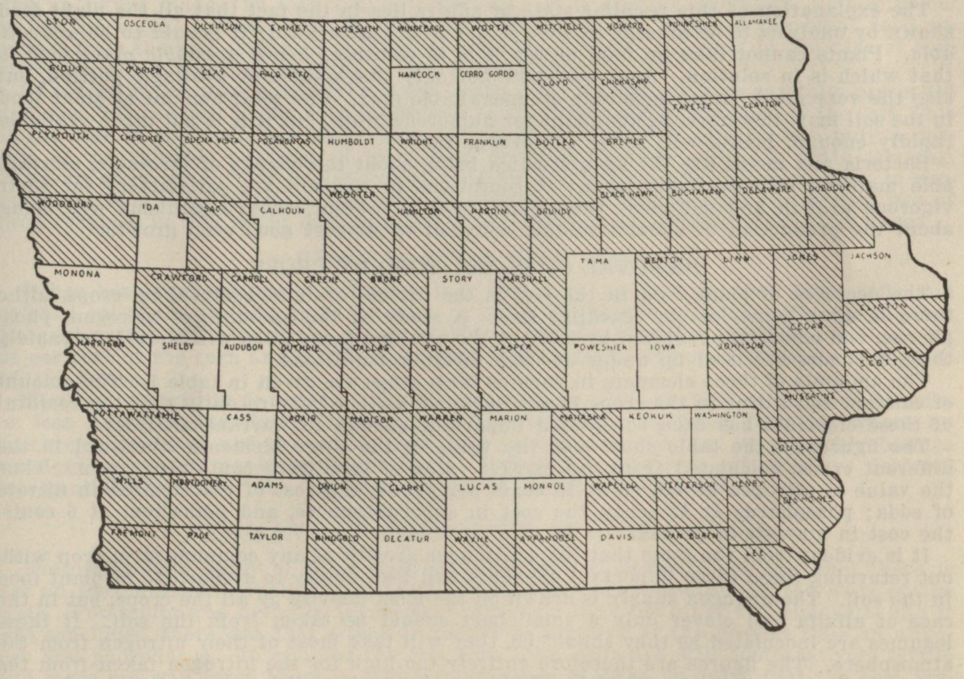

Fig. 7. Map of Iowa showing the counties surveyed.

emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested.

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

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such 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 superphosphate, and potassium at 6 cents, the cost in muriate of potash.

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

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNo_3$)), Phosphorus (P) at 12c (Superphosphate), 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	$14.3[illegible]
Corn, stover	2.25 T.	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

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 losses.

REMOVAL FROM IOWA SOILS

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

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

PERMANENT FERTILITY IN IOWA SOILS

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

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

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

CULTIVATION AND DRAINAGE

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

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

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

THE ROTATION OF CROPS

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

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

But, whatever the reasons for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that 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 the soils need be resorted to.

THE USE OF PHOSPHORUS

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

Phosphorus may be applied to soils in three commercial forms, bone meal, superphosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and superphosphate. Experiments are now under way to show which is more economical for farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and 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 superphosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

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

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown.
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. 8.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders of "nigger heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are 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 the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

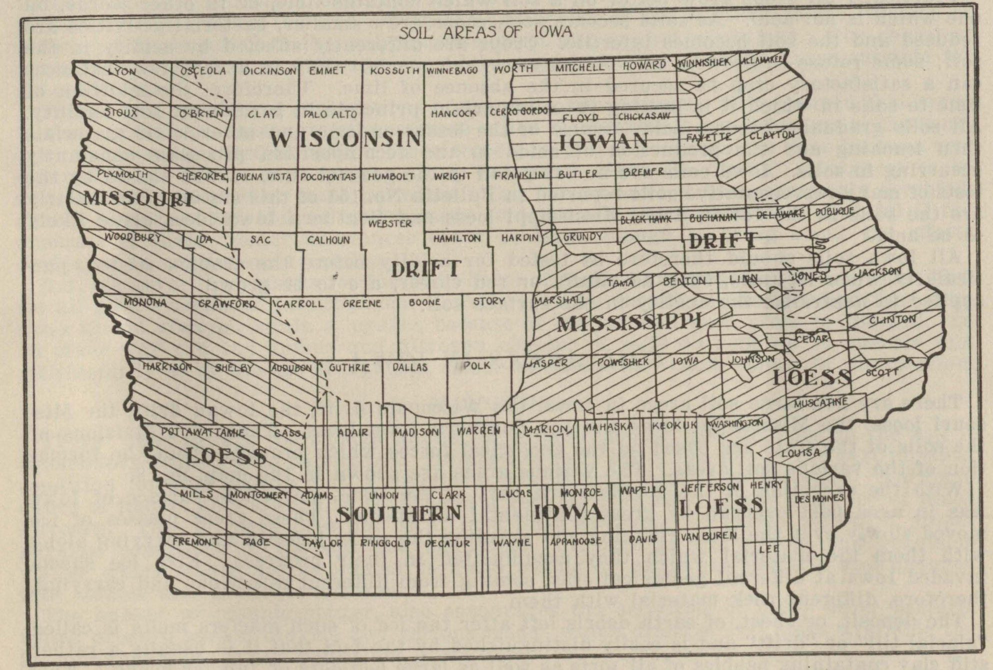

Fig. 8. Map showing the principal soil areas in Iowa.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into 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 or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical and mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

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

SOILS GROUPED BY TYPES

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

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

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

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

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

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

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

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

Loams—Less than 20 per cent clay and less than 50 per cent silt and from 30 to 50 per cent sand.

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

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

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

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

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

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

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

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

* 25mm equals 1 in. † Bureau of Soils Handbook.

Gravels—More than 50 per cent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

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

IOWA AGRICULTURAL EXPERIMENT STATION

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

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