SOIL SURVEY OF IOWA

WAYNE COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 19
April, 1921
Ames, Iowa

IOWA AGRICULTURAL EXPERIMENT STATION

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151 Soil Acidity and the Liming of Iowa Soils (Abridged).
157 Improving Iowa's Peat and Alkali Soils.*
161 Maintaining Fertility in the Wisconsin Drift Soil Area of Iowa.*
167 Rotation and Manure Experiments on the Wisconsin Drift Soil Area.
177 The Alkali Soils of Iowa
183 Soil Erosion in Iowa.
191 Reclaiming Iowa's Push Soils.

CIRCULARS

2 Liming Iowa Soils.
7 Bacteria and Soil Fertility.
8 The Inoculation of Legumes.*
9 Farm Manures.*
10 Green Manuring and Soil Fertility.*
15 Testing Soils in Laboratory and Field.*
24 Fertilizing Lawn and Garden Soils.
43 Soil Inoculation.
51 Soil Surveys, Field Experiments and Soil Management in Iowa.
58 Use of Lime on Iowa Soils.

RESEARCH BULLETINS

1 The Chemical Nature of the Organic Nitrogen in the Soil.*
2 Some Bacteriological Effects of Liming.*
3 Influence of Various Factors on the Decomposition of Soil Organic Matter.*
4 Bacterial Activities in Frozen Soils.*
5 Bacteriological Studies of Field Soils, I.*
6 Bacteriological Studies of Field Soils, II.*
8 Bacteria at Different Depths in Some Typical Iowa Soils.*
9 Amino Acid and Acid Amides as Source of Ammonia in Soils.*
11 Methods for the Bacteriological Examinations of Soils.*
13 Bacteriological Studies of Field Soils, III.
17 The Determination of Ammonia in Soils.
18 Sulfofication of Soils.
24 Determination of Amino Acids and Nitrates in Soils.
25 Bacterial Activities and Crop Production.
34 Studies in Sulfofication.
35 Effects of Some Manganese Salts on Ammonification and Nitrification.
36 Influence of Some Common Humus-Forming Materials of Narrow and of Wide Nitrogen-Carbon Ratio on Bacterial Activities.
39 Carbon Dioxide Production in Soils and Carbon and Nitrogen Changes in Soils Variously Treated.
43 The Effect of Sulfur and Manure on the Availability of Rock Phosphate in Soil.
44 The Effect of Certain Alkali Salts on Ammonification.
45 Soil Inoculation with Azotobacter.
56 The Effect of Seasonal Conditions and Soil Treatment on Bacteria and Molds in the Soil.

SOIL REPORTS

1 Bremer County.
2 Pottawattamie County
3 Muscatine County.
4 Webster County.
5 Lee County.
6 Sioux County.
7 Van Buren County.
8 Clinton County.
9 Scott County.
10 Ringgold County.
11 Mitchell County.
12 Clay County.
13 Montgomery County.
14 Black Hawk County.
15 Henry County.
16 Buena Vista County.
17 Linn County
18 Wapello County
19 Wayne County

April, 1921 Soil Survey Report No. 19

SOIL SURVEY OF IOWA

Report No. 19---WAYNE COUNTY

By W. H. Stevenson and P. E. Brown with the assistance of L. W. Forman, D. S. Gray and P. C. Weichman.

A rough area of shelby loam in Wayne county

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

CONTENTS

WAYNE COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, D. S. Gray and P. C. Weichman

Wayne county is located in central southern Iowa bordering the state of Missouri on the south. It is almost in the center of the southern boundary of the state, being the sixth county east of the Missouri river and the fifth county west of the Mississippi river. It is in the southern Iowa loess soil area and a large part of the soils of the county are loessial in origin. On a considerable area, however, there has been practically a complete removal of the loess covering and the earlier Kansan drift is exposed. Almost half of the soils of the county are derived from this drift.

The total area of the county amounts to 524 square miles or 335,360 acres. Of this area 306,197 acres, or 91.30 percent, is in farm land. The total number of farms is 1,878 and the average size is 163 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1918 show the utilization of the farm land of the county:

Acreage in general farm crops	155,629
Acreage in pasture	120,144
Acreage in farm buildings, feed lots and public highways	12,399
Acreage in waste land	749
Acreage in crops not otherwise listed	403

The type of agriculture followed in Wayne county consists mainly of general farming. The raising of stock, however, chiefly beef cattle and hogs, is receiving considerable attention. Sheep, horses and mules are also raised to some extent. In some parts of the county the livestock industry is of chief importance. The various field crops grown in the county are largely used for the feeding of cattle and hogs. Dairying is practiced to some extent and the milk, cream and butter produced are sold locally. There is one creamery in the county, located at Humeston. Fruit growing is practiced on every farm, but there are no commercial orchards in the county. The raising of poultry is practiced on a small scale thruout the county. Bee-keeping is also an industry of minor significance.

The area of waste land in the county is not very large, but large enough to demand some attention. No general recommendations can be made for the treatment of such unproductive areas, inasmuch as the causes of infertility are varied. In the discussion of individual soil types given later in this report, methods are suggested which should be followed in reclaiming waste land. Advice along this line for special conditions will be given by the Soils Section of the Iowa Agricultural Experiment Station upon request.

The general farm crops grown in Wayne county in the order of their importance are corn, oats, hay, wheat, potatoes, rye, barley, alfalfa. The acreage, yields and values of these crops are given in table I. Corn is the most important

*See soil survey report of Wayne county, Iowa, by Clarence Lounsbury of the U. S. Department of Agriculture, and P. C. Weichman and D. S. Gray of the Iowa Agricultural Experiment Station.

TABLE I. ACREAGE, YIELD, AND VALUE OF CROPS GROWN IN WAYNE COUNTY, IOWA.*

Crop	Acres	Percent of total farm land in the county	Bu. or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	70,581	23.1	24.9	1,756,324	$ 1.23	$2,160,278
Oats	38,845	12.7	40.9	1,587,259	0.64	1,015,845
Winter Wheat	4,019	1.3	16.3	65,476	1.99	130,297
Spring Wheat	604	.19	15.8	9,514	2.02	19,218
Barley	100	.03	21.2	2,124	0.89	1,890
Rye	438	.14	10.2	4,479	1.48	6,628
Hay (tame)	40,786	13.3	0.6	27,216	19.57	532,617
Hay (wild)	57	.018	1.0	72	16.00	1,152
Alfalfa	68	.022	....	88	23.93	2,105
Potatoes	131	.04	61.1	8,007	1.32	10,569
Pasture	120,144	39.0	....	......	....	......

crop, both in acreage and value. The average yield of corn for the county is 24.9 bushels per acre. Yellow dent varieties, especially Reid's Yellow Dent, are grown most extensively, some farmers, however, preferring the white varieties, especially Silver Mine. A large part of the crop produced is used for stock feeding on the farm, altho a rather considerable amount is sold out of the county. The number of silos in the county is increasing and much of the corn is being used for ensilage.

Oats is the second crop in value in the county, occupying, however, a slightly smaller acreage than hay. Average yields of oats amount to 40.9 bushels per acre. The varieties grown include the Champion, Kherson and Iowa 103. Practically all of the oats produced is fed on the farms.

Hay is the third crop in value and the second in acreage. Practically all the hay produced consists of timothy and clover mixed. Timothy is sometimes grown alone and clover is likewise occasionally grown alone for feed. In general, however, these two crops are seeded together. There is only a very small acreage of wild hay. Millet is sometimes grown as a hay crop.

Wheat is the next crop of importance in the county, the winter varieties being grown most extensively. Average yields of 16.3 and 15.8 bushels per acre for the winter and spring varieties are secured respectively. The acreage of winter wheat produced and the value of the crop in 1918 was very much greater than in the preceding years. Whether this increased acreage will be maintained now that the war demands for this crop have ended is somewhat a question. Rye is sometimes grown for winter pasturage but the area in this crop in the county is small. Barley and buckwheat are crops of minor importance. Alfalfa is grown on a small area and the value of the crop is small. With the use of lime, this crop could be very successfully grown and should prove a valuable addition to the rotations followed.

Potatoes are grown chiefly to supply the home demand and only a small amount of the crop is sold. Average yields of potatoes amount to 61.1 bushels per acre. Sweet potatoes and other vegetables are grown on small areas, chiefly to supply the home demand. Some sorghum is grown, principally for syrup.

*Iowa Yearbook of Agriculture, 1918.

The character and extent of the livestock industry in Wayne county are shown by the following figures taken from the Iowa Yearbook of Agriculture for 1918:

Horses (all ages)	12,708
Mules (all ages)	1,565
Swine (on farms July 1, 1918)	60,612
Cattle (cows and heifers kept for milk)	7,634
Cattle (other cattle not kept for milk)	25,553
Cattle (total all ages)	33,187
Sheep (all ages on farms)	22,873
Sheep (total pounds of wool clipped)	125,786

The raising of livestock, particularly beef cattle and hogs, provides the most important source of income in the county. The principal breeds of beef cattle are the Shorthorn, Aberdeen Angus and Hereford. Many farmers maintain good grade herds, and there are also a few pure-bred herds in the county. The hogs are mainly of the Duroc Jersey, Poland China or Chester White breeds. The raising of sheep, horses and mules are minor industries, only a few of the horses and mules being sold, the majority of the colts raised being used on the farm as work stock. The sheep grown are mainly Shropshire or Cotswold and a considerable amount of wool is produced and sold. The dairy products of the county are not large and the industry is of rather minor importance. The creamery at Humeston utilizes the most of the milk produced in the vicinty, a small amount being shipped to Ottumwa. In general the dairy products are largely used locally. Poultry production is practiced cheifly for supplying the home demand.

Land values in Wayne county vary somewhat, depending upon the location with reference to towns and railroad facilities, the improvements on the farms and the character of the soil. In 1918 the upland soils of the Grundy series were selling at $125 to $150 per acre and occasionally for as much as $200 per acre. Land in the Shelby loam ranged from $75 per acre in the rougher areas to about $150 for the more desirable improved areas. There has been some increase in the price of land in this county during the past year and these figures are probably a little low at present.

The soils of Wayne county, particularly those of the Grundy series, are gener-

Fig. 1. Shelby loam near Allerton.

ally fairly productive and in many cases the crop yields secured are entirely satisfactory. Considerable areas of the Shelby loam are rough to rolling in topography and probably about one-half of the total area in this type is suitable only for pasture. On the smoother portions of this soil and in the case of some areas in the other types in the county, crop production might be considerably increased by adopting better methods of soil treatment and management. It is very desirable, in fact, that much of the cultivated land be treated more carefully if crop production is to be made and kept satisfactory.

The soils of the county are practically all acid in reaction and in need of applications of lime. In most instances the acidity is large and the need of lime is very evident. The application of lime to such soils brings about very pronounced benefits on crop yields. All of the soils of the county should be tested for acidity and lime requirements and the necessary amounts of lime applied. The proper growth of crops in Wayne county, particularly of legumes, cannot be secured unless the acid conditions are remedied thru the proper applications of lime.

Much of the soil in the county is benefited by applications of farm manure. In fact, this material quite generally gives large increases in crop yields. Even on those soils which are not particularly deficient in organic matter, farm manure has proved profitable. When the production of farm manure is insufficient to provide for all the soils on the farm, leguminous crops should be grown as green manures to supplement the farm manure. These materials will also serve to maintain the nitrogen supply in the soil, and while this element is not particularly deficient in Wayne county soils, it must be supplied at regular intervals if it is not to become too low for the best crop growth. The use of the leguminous green manure crop is often necessary, even when farm manure is available, in order to keep up the nitrogen content of the soil.

The soils of the county are low in phosphorus and phosphorus fertilizers might be expected to give profitable effects at the present time. They will certainly be needed in any case in the near future. There are indications from the greenhouse tests on the soils of Wayne county and from field experiments in other counties on the same soil types, that phosphorus fertilizers may be used with profit in many cases at the present time. Complete commercial fertilizers are kept well supplied with organic matter and nitrogen. They may prove of value in some cases and when this is true they may be used without any fear of injury to the soil. Such materials should not be applied to extensive areas until tests have been made on small areas and comparisons obtained of the relative value of the complete brands with that of acid phosphate or rock phosphate. It may then be determined which material gives the most economic results.

There is need of drainage on some of the soils, particularly the Grundy clay loam and the Wabash clay loam, and in such cases the installation of tile is the first treatment needed to make the soils properly productive. It is always a profitable investment to install tile drains when soils are too wet, for while they are in this condition crop production is sure to be low. The proper rotation of crops, thoro cultivation of the soil and the return of all crop residues to the land are other methods of soil treatment which are very necessary for maintaining the best crop growth and the continued fertility of the soil.

THE GEOLOGY OF WAYNE COUNTY*

A consideration of the geology of Wayne county is of importance only in so far is the drift and loess deposits are concerned. The rock formations, which are deeply buried beneath the drift and loess coverings, are of no significance in a study of the soils of this county.

At least twice and possibly three times during the glacial age, a great glacier passed over the county and left behind upon its retreat an enormous mass of debris which it had accumulated in its forward movement over the land. The oldest ice sheet of which there is definite evidence in the county is known as the Nebraskan or pre-Kansan. An earlier glaciation may have occurred, but little trace of it remains. The thickness of the pre-Kansan deposit is extremely variable, but it is rather shallow when compared with the later deposit. Overlying the pre-Kansan deposit, a thin layer of sand and gravel is occasionally found, presumably an accumulation of the period occurring between the two glaciations. The youngest and most extensive glacial deposit is known as the Kansan. This deposit as it occurs in Wayne county varies from 40 to 400 feet in thickness and over most of the county it approaches the greater depth. It is thickest in the northwest portion of the county and is very much shallower in the northeast and southwest corners. The unweathered material making up this Kansan drift sheet is dark blue in color and very compact in structure. When exposed to weathering agencies it changes to yellow and red-brown thru oxidation and becomes less compact and impervious. The Shelby loam as mapped in Wayne county is derived from this Kansan till and a considerable area of the county is covered by this type.

At some period following the last deposit of drift over the county, there was laid down thru the agency of wind a layer of so-called loess, which is a fine-textured, silty material supposed to have been deposited under unusual climatic conditions. The loess deposit is rather shallow, usually not exceeding two feet in thickness. In many parts of the county the loess covering has been washed away, exposing the underlying Kansan till, which is mapped as Shelby loam. Almost half of the upland of the county has lost its loess covering completely and in many other sections the loess deposit is extremely thin. The loess material is a fine, clayey silt, light gray in color. Thru the accumulation of plant residues, however, it has become dark brown to black.

Two soil types are recognized as derived from the loess, both of the Grundy series, differing from each other only in texture. The bottomlands of the county are made up of the mixed drift and loess material washed down from the surrounding uplands. Where the loess material predominates, the texture of the bottomland soils is more silty in character, but where the drift material is present in the greatest amount the soil type is classed as the Wabash clay loam.

PHYSIOGRAPHY AND DRAINAGE

The topography of Wayne county is in general a gently undulating plain, cut by the various streams and drainage-ways which extend over much of the county. Deep valleys have been produced which are gradually increasing in size thru

*Iowa Geological Survey, Volume XX, page 203.

erosion and encroaching upon the intervening level uplands. The material thus removed from the uplands is deposited along the streams and has formed the various areas of bottomland occurring in the county.

There seem to be three rather distinct topographic divisions of the county, the level to undulating uplands, the flat bottomlands along the streams and the intervening areas, which are made up of a succession of ridges and valleys, relatively small in the neighborhood of the flat areas and becoming gradually steeper-sided and deeper as the larger streams are approached. This latter division is by far the largest in extent. The level bottomlands are comparatively small in total area. The uplands are more broken in topography along the larger streams, particularly along Caleb creek and the southern slopes of the South Fork of the Chariton river. The topography of these broken uplands is quite sharply defined and there is usually a very abrupt change from the level uplands to the valley slopes. There are no extensive areas of stream terraces, the only soil of the terrace type found in the county being located along the South Fork of the Chariton river.

The drainage of the county is very largely brought about thru the South Fork of the Chariton river. Approximately two-fifths of the central portion of the

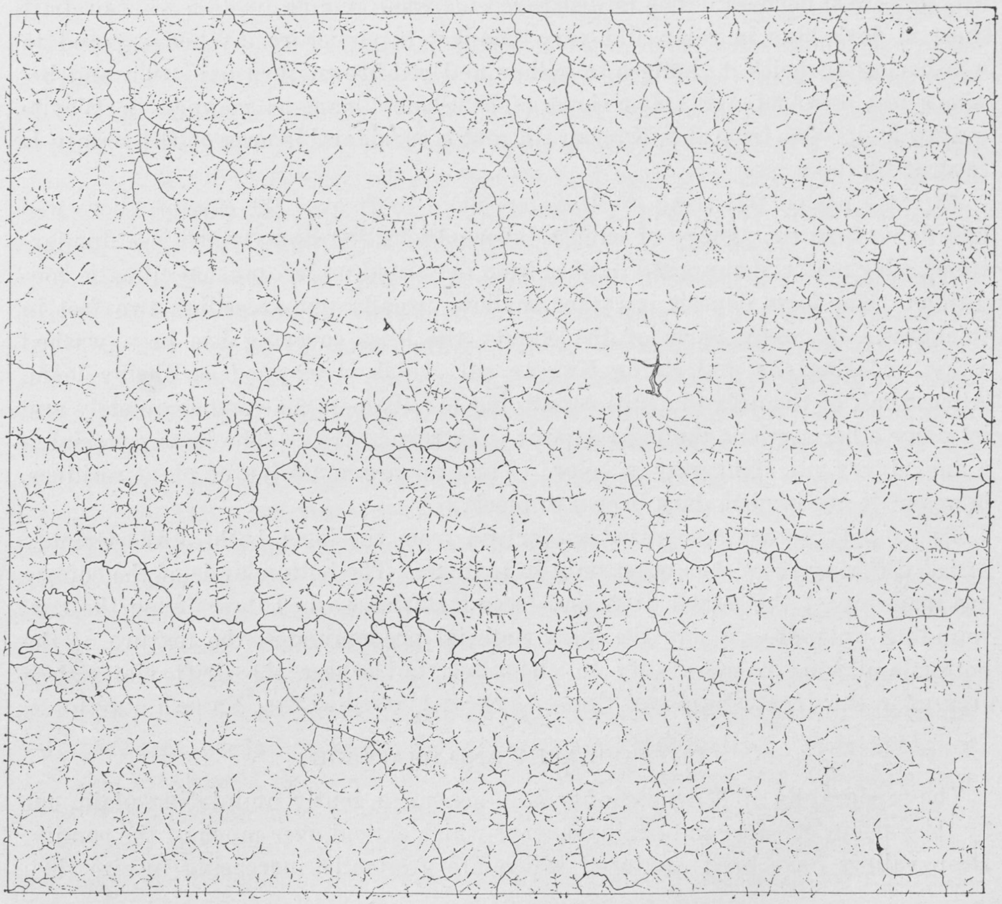


Fig. 2. Map showing natural drainage system of Wayne county.

CORRECTION—This map is in reverse position; the top is south and the bottom north.

county is drained by this river, which rises southwest of Allerton, flows northward for several miles and then turns east and continues into Appanoose county. The western part of the county is drained by Caleb and Steele creeks, which flow in a southwesterly direction into Decatur county. Along the northern boundary, several streams, flowing in a northward direction and nearly all entering the North Fork of the Chariton river in Lucas county, bring about the drainage of that portion of the county. In the southern part of the county are several streams which flow in a southeasterly direction and with their tributaries drain a considerable area. The most important of these streams are Locust creek, Fowler creek, Big Fork Medicine river, Middle Fork Medicine river and West Fork Medicine river. In the extreme east of the county three small creeks, Walnut, Cooper and Shoal, drain portions of South Fork and Walnut townships. These streams are small tributaries of the Chariton river and flow in an easterly direction into Appanoose county.

The drainage system of Wayne county in general is rather extensively developed and there are numerous intermittent drainage-ways and small streams which flow into the major streams. The extent of this drainage system is indicated in the accompanying map.

In some areas of the more level uplands, artificial drainage is desirable and this is especially true where the Grundy clay loam occurs. The largest areas of this soil type are found around Humeston west of Seymour and north of Bethlehem, smaller areas occurring in Union and Washington townships. These areas, together with some portions of the upland in Grundy silt loam, would respond to tile drainage and should be well drained if satisfactory crop production is to be secured.

THE SOILS OF WAYNE COUNTY

There are four groups of soils in Wayne county, known as drift soils, loess soils, terrace soils and swamp and bottomland soils. The various soil types of the county are classed in these groups on the basis of their origin and topographic position.

Drift soils are those which are deposited by glaciers upon their retreat. They contain material derived from various sources, usually including pebbles and boulders. Loess soils are fine, dust-like deposits made by the wind at some time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a deepening of the river channels or by a decrease in the volume of the streams by which they were formed. Swamp and bottomland soils are those occurring in low, poorly drained, areas or along streams and are subject to more or less frequent overflow.

The total acreage and percent of the area of the county included in each of these four groups of soils are shown in table II.

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

Soil groups	Acres	Percent of total area of county
Drift soils	153,024	45.6
Loess soils	158,144	47.1
Terrace soils	320	0.1
Swamp and bottomland soils	23,872	7.2
Total........................	335,360	....

The largest portion of the county, about 47 percent, is covered by the loess soils. The drift soil, the Shelby loam, is, however, almost as extensive, covering 45.6 percent of the area. The terrace soil is of very minor importance, covering only 320 acres. The two bottomland types are minor in extent, covering 5.6 and 1.6 percent of the area respectively.

The loess soils are found on the flatter upland areas and in many cases the topography of these two loess soils is practically level. The Shelby loam, however, the drift soil, is found on the rough uplands. It is this type which occurs on many of the slopes between the loessial soils of the level uplands and the bottomlands along the streams. In many cases it is very rough in topography probably not necessary, provided phosphorus carriers are used and the soil is and much of the land in this type is not suited for growing cultivated crops and must be used for pasture. It is subject to extensive erosion and it is very difficult to protect it from serious washing if it is cultivated. The terrace soil is level in topography and would be benefited by drainage, owing to the character of the soil. The bottomland types are level in topography and subject to overflow. These are also in need of drainage and especially in need of protection from overflow if they are to be made properly productive. The Wabash clay loam is not only in need of drainage but it must also be very carefully handled if the proper physical condition of the soil is to be maintained. This type is known locally as "gumbo" and if cultivated when too wet or too dry, cannot be brought into a good physical condition for crop growth. When well drained and properly handled, however, it may be made highly productive.

There are six distinct soil types in Wayne county, one drift soil, two loess soils, one terrace type and two areas of bottomland soils. The individual soil types in these groups are distinguished by certain characteristics which are discussed in the appendix to this report and the type names which are used refer to certain group characteristics. The areas of these soil types and the percent of the total area of the county covered by each type are shown in table III.

The Grundy silt loam is the most extensive individual soil type, covering over 46 percent of the total area. It is only slightly larger, however, than the Shelby

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN WAYNE COUNTY

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOIL		
79	Shelby loam	153,024	45.6
	LOESS SOILS		
64	Grundy silt loam	155,008	46.2
68	Grundy clay loam	3,136	0.9
	TERRACE SOIL		
42	Calhoun silt loam	320	0.1
	SWAMP AND BOTTOMLAND SOILS		
26	Wabash silt loam	18,624	5.6
56	Wabash clay loam	5,248	1.6

loam, the drift soil found in the county. The latter type covers 45.6 percent of the total area. These two upland types make up over 91 percent of the total area and are by far the most important types. The Grundy clay loam, the second loess type, is small in acreage, covering only 0.9 percent of the total area of the county. It is an important upland type, however, owing to its impervious character and the difficulty which is often experienced in handling it properly and also due to the fact that it is especially in need of drainage. The Wabash silt loam is the most extensive bottomland type and is the third largest type in the county. It covers 5.6 percent of the total area. The Wabash clay loam, the second bottomland type, is much less extensive in occurrence and covers only 1.6 percent of the total area.

THE FERTILITY IN WAYNE COUNTY SOILS

Samples were taken for analysis from each of the soil types in Wayne county, the more important types being sampled in triplicate, while in the case of the minor types, only one sample was drawn. All samples were taken with the greatest care that they should represent accurately the typical soil conditions and that any variations brought about by unusual local conditions or special soil treatments should be eliminated. In all cases samples were drawn at three depths, 0-6 2/3″, 6 2/3″-20″, and 20-40″, representing the surface soil, the subsurface soil and the subsoil, respectively.

Analyses were made for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The official methods were used for the phosphorus, nitrogen, and carbon determinations and the Veitch method was employed in testing for the limestone requirement. The figures given in the tables are the averages of the results secured from duplicate analyses on all samples of each type analyzed. When more than one sample of a type was taken the results are the averages of six determinations and when only one sample was taken, they are the averages of two determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil to a depth of 6 2/3″. The phosphorus content of the soils of the county is somewhat variable, ranging from 798 pounds per acre to 1899 pounds per acre. The Shelby loam is the lowest in phosphorus of all the soils, and the clay loams are the highest. The Wabash silt loam and the Grundy silt loam are somewhat higher than the Shelby loam and lower than the clay loams in this constituent. None of the types are particularly well supplied. These comparisons cannot be considered very important, however, inasmuch as the differences in the amount of phosphorus present are not very large. If any conclusions were to be drawn from the comparison of the phosphorus in the various types, it might be said that the clay loams are somewhat richer in this constituent than the silt loams. This is in accord with other results which have been secured on the soils of other counties.

Phosphorus is not actually deficient in any of the soils of this county, but it is evident that the supply is so low that there is some question regarding the proper supply of the element in an available form. Phosphorus fertilizers will un-

TABLE IV. PLANT FOOD IN WAYNE COUNTY, IOWA, SURFACE SOILS

Pounds per acre of Two Million Pounds of Surface Soil (0"-6 2/3")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limest'n requirement
	DRIFT SOIL					
79	Shelby loam	798	3,404	32,800	0	4,052
	LOESS SOILS					
64	Grundy silt loam	1,073	3,787	46,400	0	4,767
68	Grundy clay loam	1,865	5,254	65,200	0	2,860
	TERRACE SOIL					
42	Calhoun silt loam	1,589	3,110	38,800	0	2,145
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,077	4,582	53,000	0	3,575
56	Wabash clay loam	1,899	5,100	64,800	0	2,145

doubtedly be needed in the near future if the soils are to be kept properly productive and it seems quite probable that in many cases they can be used with profit at the present time. It is very desirable that farmers test the value of rock phosphate and acid phosphate and thus determine for their own soil conditions not only the value of applying phosphorus, but the relative value from the use of the two materials. Field experiments are now under way in other counties on some of the soil types which also occur in Wayne county and the results should be applicable to conditions in Wayne county. Experimental data from these fields is far from complete at the present time, however ,and definite conclusions cannot yet be drawn. There are indications of the value of prosphorus from these tests, some of which will be mentioned later in this report, but in the meantime tests on individual farms are strongly recommended.

The nitrogen content of the soils of the county is not low; neither is it very high in any case. The relations between the amount of this constituent and the various soil types are very much the same as were noted in the case of phosphorus. The Grundy clay loam and Wabash clay loam show the largest amount of nitrogen, larger than the silt loams of the same series. The Grundy clay loam shows a content of 5,254 pounds. This is the largest amount in any of the types in the county. The Calhoun silt loam contains 3,110 pounds per acre, which is the smallest amount in any of the soils. It is apparent, therefore, that no definite comparisons can be made between the content of nitrogen and the soil types or soil groups. It is evident merely that the clay loams are better supplied than are the silt loams.

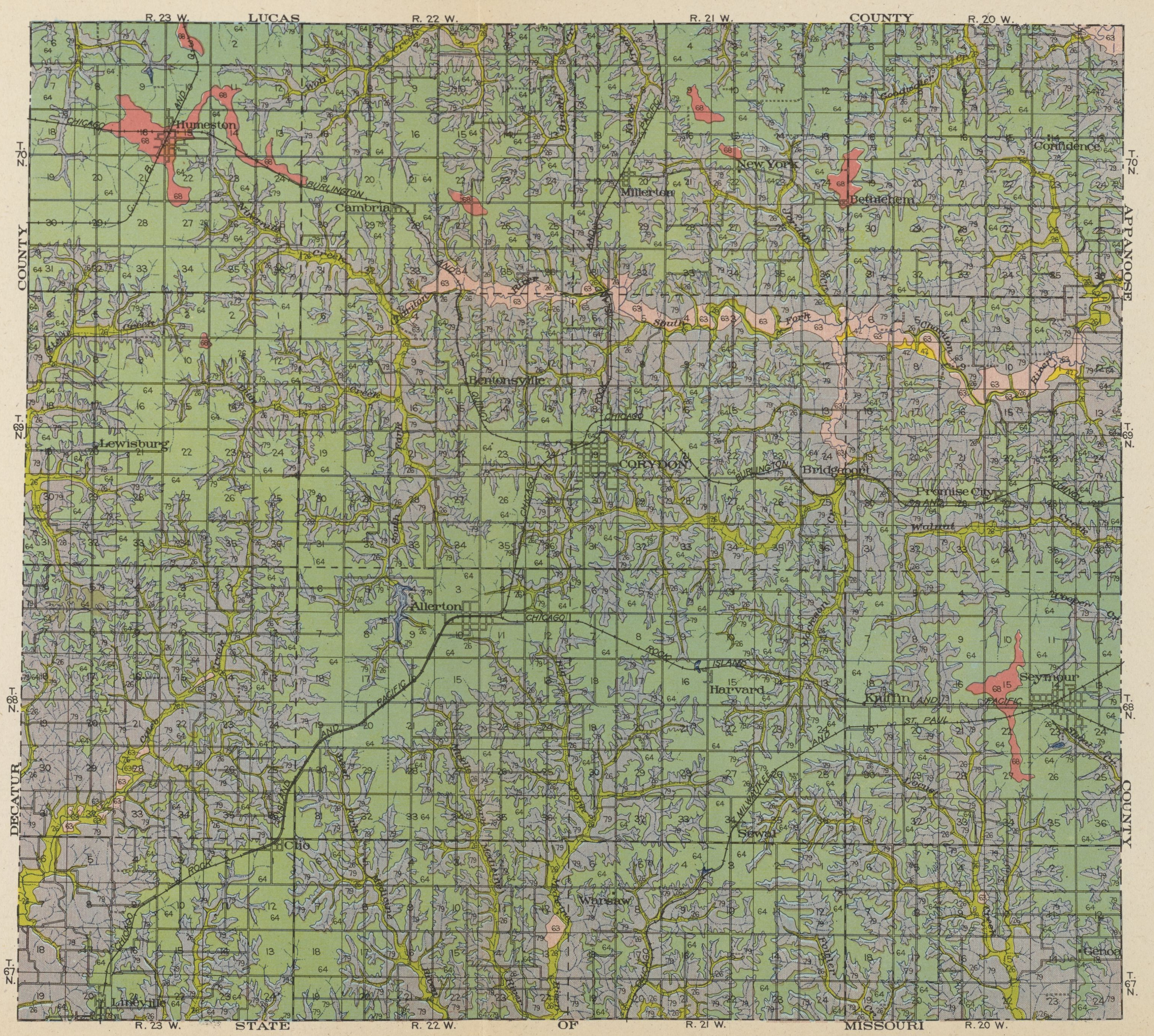
Altho the nitrogen content is not low, the supply of this element must be kept up if the soil is to be maintained in a proper condition of fertility. There is always some loss of nitrogen by leaching and much utilization by crops, and any system of fertility must take into account the return of this constituent. Crop residues should all be returned to the soil and farm manure should be used in as large amounts as practicable and these materials will provide for a considerable

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

SOIL MAP OF WAYNE COUNTY

Thomas D. Rice, Inspector Northern Division—Soils surveyed by Clarence Lounsbury of the U. S. Department of Agriculture, in charge, and P. C. Wiechmann and Donald S. Gray of the Iowa Agricultural Experiment Station.

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



LEGEND

Drift Soils

79 — Shelby loam

Loess Soils

64 — Grundy silt loam

68 — Grundy clay loam

Terrace Soils

42 — Calhoun silt loam

Swamp and Bottomland Soils

26 — Wabash silt loam

63 — Wabash clay loam

Scale: 1 Inch 2½ Miles

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return of the nitrogen removed by crops. It is often necessary, however, to employ additional means of supplying nitrogen and this may be accomplished by growing some leguminous crop and turning it under as a green manure. Such crops, when well inoculated, take a considerable part of their nitrogen from the atmosphere and are therefore of distinct value when turned under in the soil because of the actual addition of this element. They are also of value because of the organic matter which they supply. The use of legumes as green manures is a very desirable farm practice to supplement the use of farm manure and to increase and maintain the nitrogen and organic matter in the soil.

The organic carbon present in the soil is a measure of the amount of organic matter present and it is also an indication of the nitrogen supply. There is usually a rather definite relation evidenced between the organic carbon and nitrogen in the soils. A large amount of the former generally indicates a considerable supply of the latter and vice versa. The color of the soils indicates rather definitely the content of organic matter and hence of organic carbon and nitrogen. Light colored soils are low in these constituents, while dark colored types are very much better supplied. The soils of Wayne county are largely dark in color, hence indicating a rather considerable supply of organic matter. The determinations of the organic carbon in the soils bear out this conclusion. In no case is there any striking deficiency in organic carbon, the smallest amount being present in the drift soil, the Shelby loam. The largest supply is found in the Grundy clay loam, just as was true of the nitrogen. The Wabash clay loam is also very well supplied. As was noted in the case of nitrogen, the clay loams seem to possess a larger amount of organic carbon than the silt loams of the same series. These are the only relations evidenced among the various soils of the different groups.

It is interesting to note that the Shelby loam, derived from the old Kansan till, is the poorest in organic matter. This soil is particularly benefited by the application of manure or other materials supplying organic matter. The Calhoun silt loam would also be largely benefited by the use of farm manure, but even those soils which are apparently well supplied with organic matter respond to applications of manure and sometimes also to treatment with green manure. The Grundy silt loam, for instance, as will be shown in the field experiments described later, gives remarkable crop increases when manure is applied. Many experiments and much farm experience indicate that farm manure is a particularly valuable fertilizing material for use on the soils of this county.

There is no inorganic carbon present in any of the soils of the county and they all show a rather considerable lime requirement by the Veitch method. The Grundy silt loam and the Shelby loam show particular need for the use of lime, altho no definite conclusions should be drawn from the tests of only a few samples of a soil type. Soils vary widely in lime requirement, even when of the same type, and the results given in the table should be considered merely indicative of the needs of the soils of the county. Every soil should be tested for its lime requirement before an application is made in order that the exact amount needed may be determined and the proper amount applied. It is apparent from the results given in the table, however, that the soils of the county are all acid in reaction and they should therefore be tested for acidity and the amount of lime

Fig. 3. Clover on Grundy silt loam, Wayne county.

needed should be added if the best growth of crops, particularly of legumes, is to be secured.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. These are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil. The fertility of the soil is influenced to a very slight extent by the plant food present in the lower soil layers, except when the amount present is very large. It is evident from the tables that the lower depths soils of this county are not excessively supplied with any plant food constituent, therefore the plant food in the lower soil layers has no particular influence upon the fertility of the cultivated soils of the county, and the results given in tables V and VI need not be considered in detail. In general, however, it may be noted that they very largely confirm the conclusions reached from the study of the composition of the surface soils.

TABLE V. PLANT FOOD IN WAYNE COUNTY, IOWA, SUBSURFACE SOILS.
Pounds per acre of Four Million Pounds of Subsurface Soil (6 2/3"-20")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limest'n requirement
	DRIFT SOIL					
79	Shelby loam	1,262	4,148	50,800	0	8,103
	LOESS SOILS					
64	Grundy silt loam	1,872	3,793	45,466	0	6,055
68	Grundy clay loam	4,202	6,836	84,616	984	Basic
	TERRACE SOIL					
42	Calhoun silt loam	2,559	2,044	22,800	0	5,005
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	3,663	8,940	104,000	0	5,720
56	Wabash clay loam	3,017	7,200	99,200	0	2,345

TABLE VI. PLANT FOOD IN WAYNE COUNTY, IOWA, SUBSOILS

Pounds per acre of Six Million Pounds of Subsoil (20"-40")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limest'n requirement
	DRIFT SOIL					
79	Shelby loam	2,707	3,306	36,000	0	10,725
	LOESS SOILS					
64	Grundy silt loam	3,057	4,542	42,533	0	4,290
68	Grundy clay loam	2,949	2,940	27,924	1,476	Basic
	TERRACE SOIL					
42	Calhoun silt loam	3,758	3,786	34,200	0	8,580
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	4,728	8,490	113,400	0	6,435
56	Wabash clay loam	2,061	4,332	61,200	0	3,517

The treatments needed by the soils of the county include, therefore, the use of phosphorus fertilizers, the addition of organic matter and nitrogen and the application of lime. The Grundy clay loam is not acid in its subsurface and subsoil, but there is no considerable amount of lime present and very little influence from the amount present would be evidenced on the lime requirement of the surface soil. In all the other types the lower soil layers are acid and show a need of lime. The soils of the county should evidently all be tested for acidity regularly and as the lime applied to the surface goes down into the subsoil, further addition of the material will serve to neutralize the acid conditions there.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on the soils of Wayne county in order to obtain some idea of the value of various fertilizing materials. One of these was on the Grundy silt loam and the other on the Shelby loam, the two main types in the county. These tests were carried out according to the same plan, with similar treatments. Manure was added at the rate of 8 tons per acre; lime in a sufficient amount to neutralize the acidity of the soil and two tons additional; rock phosphate at the rate of 2,000 pounds per acre; acid phosphate at the rate of 200 pounds per acre, and a complete commercial fertilizer, a standard 2-8-2 brand, at the rate of 300 pounds per acre. Wheat and clover were grown in the pots in both cases, the clover being seeded about one month after the wheat was up.

The results given in table VII show the average yields of wheat and clover obtained in the experiment on the Grundy silt loam. The application of manure brought about a distinct increase, both in the crop of wheat and the crop of clover, the effect being particularly noticeable in the case of the clover. When lime was applied with manure, no additional increase was noted with either crop. Slightly smaller yields are recorded on the average, but they merely indicate no additional value from the lime. Rock phosphate increased the wheat yield slightly and brought about a distinct increase in the clover crop. Acid phosphate showed less effect than the rock in the case of the wheat crop, but

TABLE VII. GREENHOUSE EXPERIMENT

Grundy silt loam—Wayne county.

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	23.0	40.82
2	Manure	26.0	52.16
3	Manure+Lime	25.7	49.89
4	Manure+Lime+Rock Phosphate	27.0	58.96
5	Manure+Lime+Acid Phosphate	25.5	63.50
6	Manure+Lime+Complete Commercial Fertilizer	24.0	54.43

proved of more value than the rock when applied on clover. The complete commercial fertilizer brought about no effect in the case of the wheat and proved less effective than either the rock or acid in the case of the clover.

Evidently manure is a very valuable fertilizing material for use on this soil. There are indications of value also from the application of phosphorus, particularly in the case of clover. Results do not permit of comparisons between the two forms of phosphorus, but the evidence points to the desirability of testing these materials in the field.

The average results from the duplicate tests on the Shelby loam from Wayne county are given in table VIII. The application of manure again brought about a distinct increase in the growth of both wheat and clover. The use of lime with manure had no effect in the case of the wheat, but showed an increase on the clover. Rock phosphate gave a slight increase in the wheat crop and also a

Fig. 4. Wheat on Grundy silt loam, Wayne county.

Fig. 5. Wheat on Shelby loam, Wayne county.

slight increase in the clover. Acid phosphate also increased the yields of both crops to a small extent, the results being almost exactly the same as those obtained with the rock. The complete commercial fertilizer increased both the wheat and the clover crops to a larger extent than did the phosphate fertilizers. The differences, however, are not large enough to be very distinctive. It is apparent from these results that manure is a particularly valuable material to use on these soils and there are indications of value from the use of a phosporus fertilizer in addition to manure. Field experiments are certainly desirable on the Shelby loam to determine whether rock or acid phosphate should be employed. The value of lime is shown by the effect of the addition of this material to the Shelby loam when clover is grown. It would not be expected that lime would influence the wheat crop and the value of applying lime to this soil type

TABLE VIII. GREENHOUSE EXPERIMENT

Shelby loam—Wayne county

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	18.0	36.28
2	Manure	28.0	40.82
3	Manure+Lime	28.0	43.09
4	Manure+Lime+Rock Phosphate	29.0	45.36
5	Manure+Lime+Acid Phosphate	28.5	45.36
6	Manure+Lime+Complete Commercial Fertilizer	30.2	----

Fig. 6. Clover pot culture on Grundy silt loam in Wapello county.

would be looked for on the legume used in the rotation. This soil should evidently be tested for acidity and lime applied as needed.

Two greenhouse experiments were carried out on the Grundy silt loam in Wapello county and the results of these experiments are included here, inasmuch as the soil type is the same and the conditions are very similar. These experiments were carried out in exactly the same way as has been described and the results of these tests are given in tables IX and X.

Manure showed a very slight effect on the two crops in this experiment, increases being noted, however, in both cases. The yield of wheat was not secured on the manure-lime pots and no effect was evidenced from the use of lime on the clover. This is rather surprising, but the results should not be taken to mean that lime will not prove of value on this soil when it is acid. It will be noted in other tests on this soil that lime proved of some effect and in general it may be said that farm experience indicates quite definitely the value of the use of lime on this soil when it is acid. The application of rock phosphate increased both the wheat and clover crops to a small extent, the effect being more evident on the clover than on the wheat. Acid phosphate increased the wheat crop to a somewhat greater extent than did the rock phosphate and in the case of the clover, the acid phosphate proved very efficient. The complete fertilizer was about as effective as the acid phosphate on the wheat, but proved more effective on the clover. The increase from the use of this material on the latter crop was very large. These results serve to show the value of manure on this soil and to

TABLE IX. GREENHOUSE EXPERIMENT

Grundy silt loam—Wapello county, 1917

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	35.2	45.3
2	Manure	36.7	47.6
3	Manure+Lime	----	47.6
4	Manure+Lime+Rock Phosphate	37.5	49.8
5	Manure+Lime+Acid Phosphate	38.5	56.7
6	Manure+Lime+Complete Commercial Fertilizer	38.0	63.5

TABLE X. GREENHOUSE EXPERIMENT

Grundy silt loam—Wapello county, 1918

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	18.1	33.0
2	Manure	17.8	34.0
3	Manure+Lime	18.4	37.0
4	Manure+Lime+Rock Phosphate	24.4	48.0
5	Manure+Lime+Acid Phosphate	18.2	55.0
6	Manure+Lime+Complete Commercial Fertilizer	21.1	38.0

indicate quite definitely that phosphorus fertilizers may prove of considerable value.

The test on the Grundy silt loam, in 1918, was carried out in the same way as in the preceding year. The results of this test are given in table X.

Manure showed a slight effect on the clover in this experiment, but gave no effect on the wheat crop. Lime in addition to manure proved of value to both crops, a distinct increase being obtained in the case of the clover. Rock phosphate increased the yields of both crops to a large extent. Acid phosphate proved of practically no effect on the wheat, but the clover crop was increased to a larger extent with this material than by the use of rock phosphate. The complete commercial fertilizer increased the wheat yield to a smaller extent, however, than did the rock phosphate. The effect on the clover was small, the acid and rock phosphates both showing up much better on this crop. These

Fig. 7. Tests on Grundy silt loam in Wapello county show the value of manure, lime and a phosphate fertilizer for wheat.

results confirm very largely the results obtained on the same soil the preceding year and they show the value of manure, lime and a phosphate fertilizer.

These greenhouse experiments, as a whole, indicate quite definitely that the two main soil types of Wayne county will respond to applications of manure, lime and probably also to phosphorus fertilizers. The indications from these tests are borne out by the field experiments from other counties on the same types and they are also confirmed by much farm experience, especially the conclusions regarding manure and lime. The desirability of testing the soils for need of phosphorus is indicated from these results and from the field tests Whether or not rock phosphate or acid phosphate should be employed must be determined by tests in the field extending over a period of years. The individual farmer may test these materials most satisfactorily on his own farm and obtain rather definite conclusions regarding their value for his particular conditions.

FIELD EXPERIMENTS

There are no field experiments under way at the present time in Wayne county, but several are being carried out in Wapello and Henry counties on the Grundy silt loam. Inasmuch as this is a very important type in Wayne county and the conditions here are very much the same as in the other counties mentioned, the results secured to date on several of the fields in Wapello and Henry counties will be reproduced here.

In each of these experiments a series of plots was laid out 155′ 6″x28′, or 1/10 of an acre in size. Each test includes the soil treatments which should be practiced both in the livestock system of farming and in the grain system. In the former, manure is applied, while in the latter, crop residues are employed to supply the organic matter. The applications tested in all of the experiments and under both systems of farming, are limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure is applied on the livestock system plots at the rate of 8 tons per acre once in a four-year rotation. On the grain system plots, the second crop of clover is plowed under, the corn stalks are cut with a disc and plowed under and all the straw from the small grains is returned to the soil. Lime is added in sufficient amounts to neutralize the acidity of the soil and supply two tons additional Rock phosphate is applied at the rate of 2000 pounds per acre once in a rotation. Acid phosphate is added at the rate of 200 pounds per acre annually and a standard 2-8-2 complete commercial fertilizer is used at the rate of 300 pounds per acre annually. There are 13 plots in each of the experiments, three of which are untreated or check plots. Plots 1 to 7, inclusive, represent the livestock system, while plots 7 to 13 represent the grain system of farming. The results on the crop residue plots are not included here, owing to the fact that they are somewhat irregular and in all cases there has been no opportunity for the residues to show any effect.

THE FARSON FIELD

Three experiments are being carried out on the Grundy silt loam near Farson in Wapello county. These are known as Series I, II and III. The results obtained on Series I are given in table XI. The effect of manure is shown very

TABLE XI. FIELD EXPERIMENT

Grundy silt loam—Wapello county, Farson Field, Series I

Pot No.	Treatment	Winter Wheat bushels per acre 1918	Clover Tons per acre 1919
1	Check	16.9	1.95
2	Manure	20.3	2.80
3	Manure+Lime	22.6	2.65
4	Manure+Lime+Rock Phosphate	23.7	2.80
5	Manure+Lime+Acid Phosphate	20.9	2.85
6	Manure+Lime+Complete Commercial Fertilizer	19.2	3.05
7	Check	16.9	2.85

definitely in this experiment both on the winter wheat in 1918 and on the clover in 1919. In fact, the application of other fertilizing materials in addition to the manure gave very much less striking effects than did the manure alone. Lime showed a small effect on the wheat, and rock phosphate in addition to manure and lime increased the yield of this crop to a slight extent. The other phosphorus carriers, however, showed no influence on this crop. In the case of the clover the complete commercial fertilizer was the only material which gave any effect. This test indicates very clearly the beneficial effect of manure on the Grundy silt loam and there are indications also of value from the use of a phosphorus fertilizer. Further results are of course necessary before definite conclusions can be reached.

The results of the second test on the Farson field on the same soil type are given in table XII. These results are much less definite than those obtained in Series I. There is some effect of the manure, however, on the oats in 1918, as shown by a comparison of the average of the checks with the manure treated plot. Neither the rock phosphate nor the acid phosphate showed any influence on the oats, but the complete commercial fertilizer gave a small increase. In the case of the wheat the application of manure and lime increased the yield considerably and rock phosphate in addition brought about a further increase. With this crop the acid phosphate and complete commercial fertilizer showed little effect. These results, while not very definite, do serve to confirm the preceding, however, and show the value of manure and the possibility of economic returns from the application of phosphorus fertilizers.

The results of Series III on the Grundy silt loam are given in table XIII. The application of manure increased the yield of corn in 1918 considerably, but brought about no effect on the oats in 1919. The addition of rock phosphate

TABLE XII. FIELD EXPERIMENT

Grundy silt loam—Wapello county, Farson field, Series II.

Plot No.	Treatment	Oats bushels per acre 1918	Wheat bushels per acre 1919
1	Check	72.2	11.7
2	Manure	72.2	11.7
3	Manure+Lime	70.0	15.2
4	Manure+Lime+Rock Phosphate	72.2	16.1
5	Manure+Lime+Acid Phosphate	70.0	14.8
6	Manure+Lime+Complete Commercial Fertilizer	74.3	14.6
7	Check	68.0	14.6

TABLE XIII. FIELD EXPERIMENT

Grundy silt loam—Wapello county, Farson Field, Series III

Plot No.	Treatments	Corn bushels per acre 1918	Oats bushels per acre 1919
1	Check	63.0	50.3
2	Manure	66.0	44.9
3	Manure+Lime	66.5	50.3
4	Manure+Lime+Rock Phosphate	69.7	44.9
5	Manure+Lime+Acid Phosphate	68.7	53.0
6	Manure+Lime+Complete Commercial Fertilizer	65.7	....
7	Check	54.0	45.6

along with manure and lime showed some effect on the corn but none at all on the oats. Acid phosphate increased the corn yield to a less extent, however, than did the rock phosphate. In the case of the oats the reverse was true, acid phosphate giving a distinct increase in the crop yields. The complete commercial fertilizer showed no effect on the corn and the yield of the oats in 1919 was not secured. Again the effect of manure is shown on this soil type and there are evidences of value from the phosphorus fertilizers.

THE AGENCY FIELD

The results obtained on the field at Agency in Wapello county on the Grundy silt loam are given in table XIV.

The beneficial effect of manure on this soil type is evidenced both in the case of the corn and in the case of the oats, the influence on the latter crop being very pronounced. Lime proved of some value, altho any effect from this material would not ordinarily be expected on these crops. Rock phosphate increased the yields of both the corn and oats and acid phosphate gave still larger increases in the case of both crops. The complete commercial fertilizer proved less effective than the phosphorus carriers. The results of this test confirm those obtained on the various series on the Farson field and show very distinctly the beneficial effect of manure and increases from the use of phosphorus fertilizers.

THE MT. PLEASANT FIELD

The results obtained on the Mt. Pleasant field, Henry county, are given in table XV. This field is located on the Grundy silt loam. The results secured for the years 1917, 1918 and 1919 on the two series of plots on this field show some interesting results of treatment. In the case of the corn and oats crop, the yield on the check plot is determined by averaging the three check yields. With

TABLE XIV. FIELD EXPERIMENT

Grundy silt loam—Wapello county, Agency Field

Plot No.	Treatments	Corn bushels per acre 1918	Oats bushels per acre 1919
1	Check	63.5	44.9
2	Manure	64.5	62.2
3	Manure+Lime	66.7	58.3
4	Manure+Lime+Rock Phosphate	68.7	63.6
5	Manure+Lime+Acid Phosphate	70.0	66.6
6	Manure+Lime+Complete Commercial Fertilizer	66.0	65.6
7	Check	59.2	54.5

TABLE XV. MT. PLEASANT FIELD EXPERIMENT

HENRY COUNTY—GRUNDY SILT LOAM

Plot No.	Treatment	1917		1918		1919	
		100 Series Corn bu. per acre	200 Series Oats bu. per acre	100 Series Oats bu. per acre	200 Series Clover lbs. per acre	100 Series Clover lbs. per acre	200 Series Corn bu. per acre
1	Check	48.1	93.1	73.7	7883	8300	57.3
2	Manure	37.5	85.0	75.1	9650	7580	66.3
4	Manure+Limestone	52.2	90.0	74.8	10600	7990	74.1
4	Manure+Limestone+Rock Phosphate	66.0	107.5	76.5	11450	9860	78.6
5	Manure+Limestone+Acid Phosphate	73.6	97.5	85.1	12575	12950	75.3
6	Manure+Limestone+Commercial Fertilizer	76.8	97.5	80.8	10850	13870	66.5
7	Check*	48.1	93.1	73.7	4575	4380	57.3
8	Crop Residue	50.8	91.3	81.3	5650	4600	65.3
9	Crop Residues+Limestone	47.1	92.5	93.2	4250	4450	71.0
10	Crop Residues Limestone +Rock Phosphate	52.7	100.0	96.4	5985	5700	75.1
11	Crop Residues+Limestone +Acid Phosphate	54.1	92.5	99.9	6545	6420	81.1
12	Crop Residues+Limestone +Commercial Fertilizers	52.8	107.5	93.6	5390	6300	78.5

the clover, however, this can only be done in the livestock system plots. In the grain system plots the checks are the average of plots 7 and 13, which adjoin the crop residue treated plots, and are the average of the first cutting yields only. It has been necessary to eliminate the oat yield in one instance, owing to the very evident error which must have occurred in obtaining the weight of the sample.

In one or two cases the effects of treatment are not evident, or at least they are not what would be expected, probably due to unavoidable irregularities in the soil conditions in the plots. For instance plot 2, treated with manure, shows a slightly lower yield of corn than the average checks, a slightly lower yield of oats than the checks and a slightly lower yield of clover than the checks. This variation occurs especially in the 100 series, but it also noted in the 200 series.

In general, however, the effects of the application of fertilizing materials are really very definite and attention should especially be called to the effect of the phosphate fertilizers. It will be noted that the rock phosphate and the acid phosphate brought about considerable increases in yields of corn, oats, and clover in each test, both under the livestock system and under the grain system. The results are hardly complete enough, however, to permit of definite conclusions regarding the relative merits of these two materials. In some cases the rock seems to be a little better, but in most instances the acid phosphate seems to show the larger gains. The differences, however, are not very large and unless succeeding years' results enlarge considerably the gains from the acid phosphate, it is hardly likely that the material will prove to be as economically profitable as the rock phosphate. From these results, however, it would seem quite evident that some phosphate fertilizers should be used on the Grundy silt loam and

*The check yields given under 7 are the same as under 1 in the case of corn and oats—the figures being the average of the three check plots. In the case of the clover, however, the yields in 7 are the average of the first clover crop on plots 7 and 13—the second being turned under on the crop residue plots. The clover yields in 1 are the average of both clover crops on all three check plots.

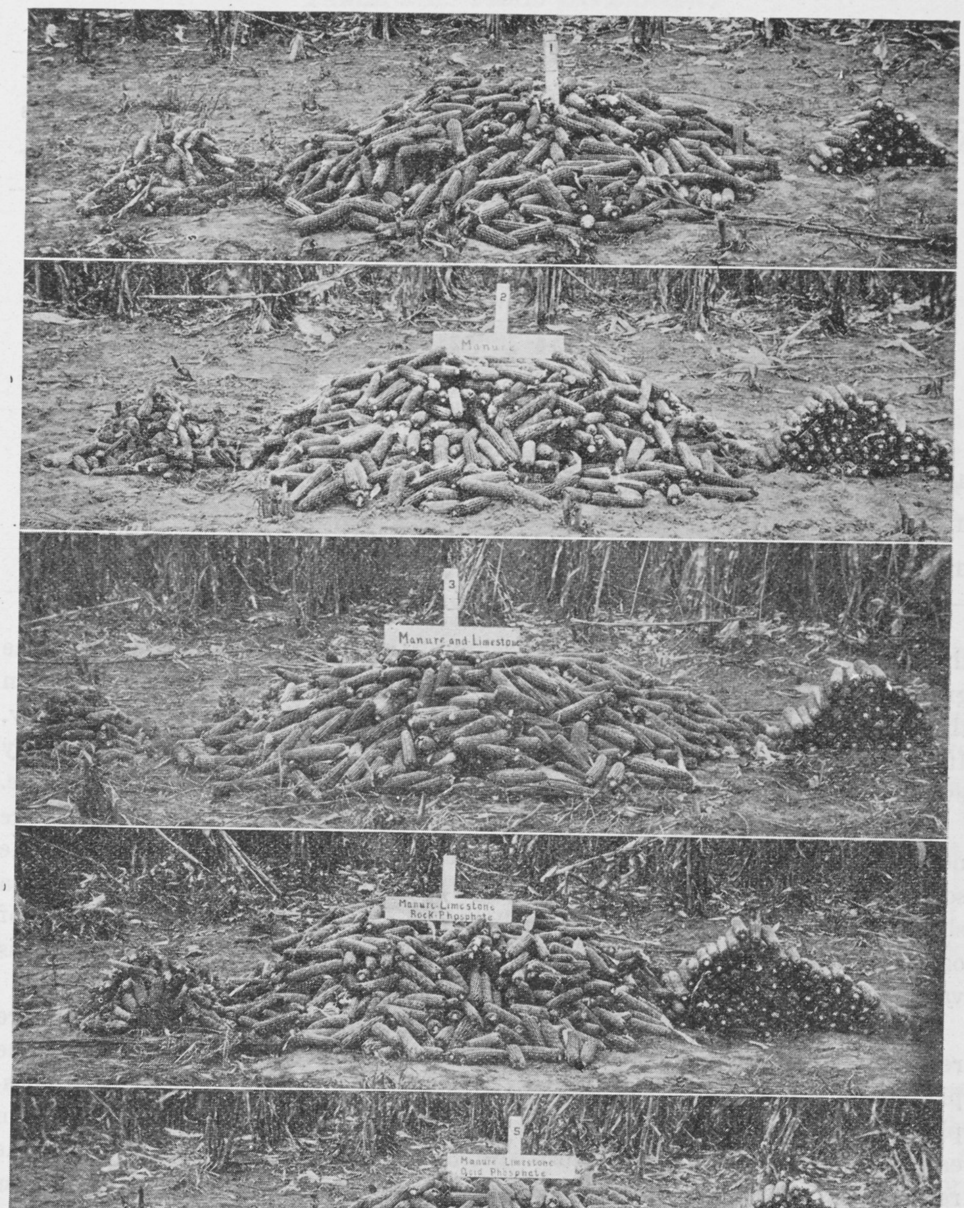

Plate I. Field Experiment at Mount Pleasant on Grundy silt loam—livestock system, 1919. Yield of corn per acre, check plot, 55.7; with manure, 66.3; manure and limestone, 74.1; manure, limestone and rock phosphate, 78.6; manure, limestone and acid phosphate, 75.3. Center piles, good, marketable corn; to the right, seed corn; to the left, nubbins. Check plot No. 1 shown. Results in the test are the average of all checks (1, 7 and 13).

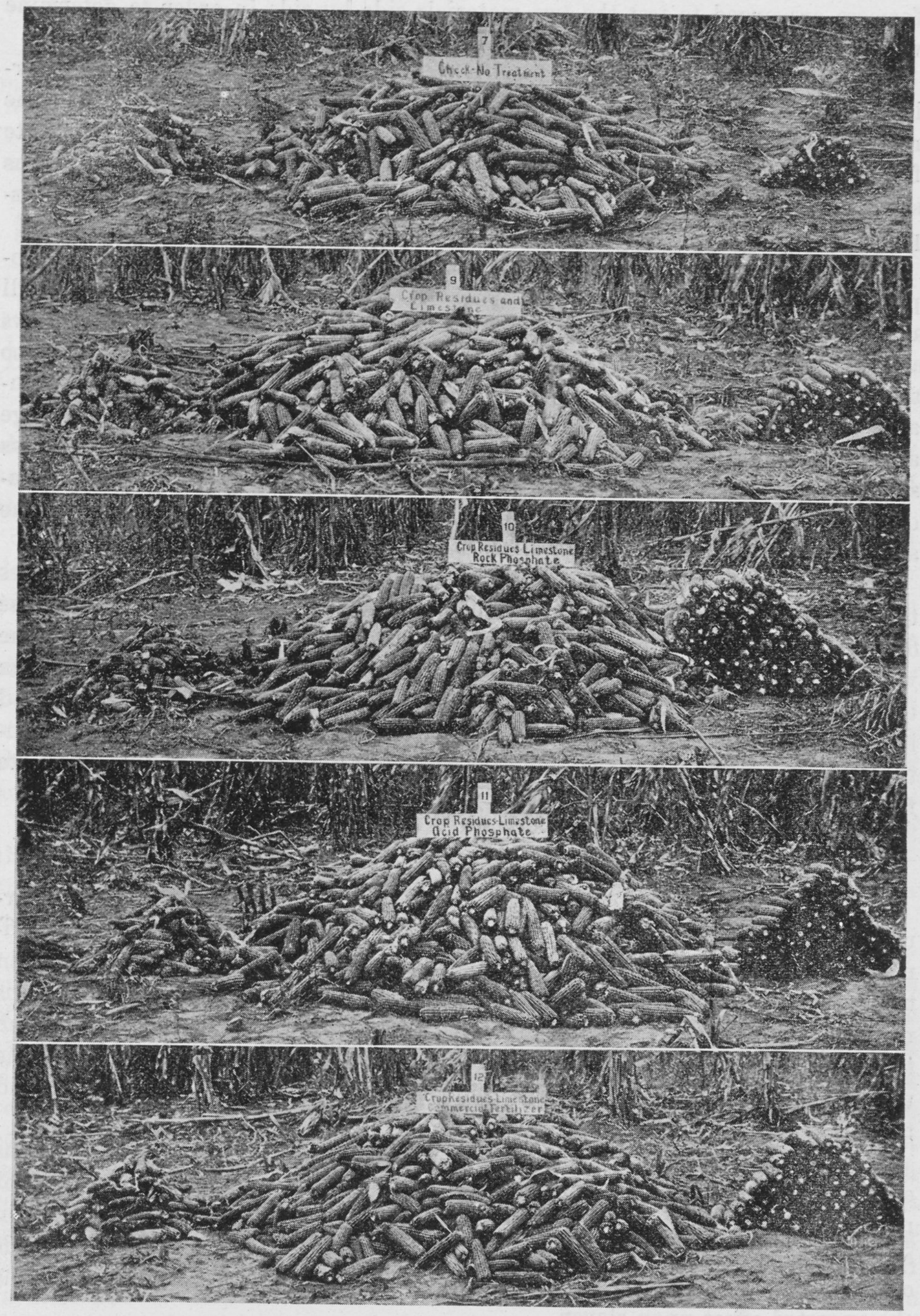

Plate II. Field experiment at Mt. Pleasant on Grundy silt loam—grain system, 1919. Yield of corn per acre, check plot, 50.6; with crop residues and limestone, 65.3; crop residues, limestone and rock phosphate, 71.0; crop residues, limestone and acid phosphate, 75.1; crop residues, limestone and commercial fertilizer, 78.5. Center piles, good, marketable corn; to the right, seed corn; to the left, nubbins. Check plot No. 7 shown. Results in the text are the average of all checks (1, 7 and 13).

farmers are urged to test the two materials side by side in order to determine which is the more valuable for their particular conditions.

The complete commercial fertilizer, with few exceptions, showed no superiority over acid phosphate and in some instances it gave a smaller effect than the rock phosphate. It would seem, therefore, that the larger cost of the complete fertilizer would hardly be warranted on this particular type of soil and quite as satisfactory results may be secured by using one or the other of the cheaper phosphate materials.

Owing to the irregular soil conditions in plot 2, already mentioned, the application of manure does not show up so well as would be expected, nor so well as is commonly the case in general farm practice. The clover yield in 1918 shows a large increase from the use of manure, however, and the corn in 1919 also shows the effect of manure. There is no question but that manure is a very valuable fertilizing material for use on this soil and it should be applied in as large amounts as practicable to insure the continued fertility of the soil. Lime shows some increase in crop yields, particularly in the case of clover, and this would indicate the need of testing the Grundy silt loam to determine its reaction and the amount of lime required to put it in a basic condition.

The experiment has not been continued long enough for the crop residues to give much effect. The corn yield in 1919, however, showed a distinct increase on the crop residue plots where the second crop of clover was plowed under. The yield for the next two or three years should show even more definite effects from this method of handling the clover crop. These results as a whole give a good indication of the requirements of the Grundy silt loam for increased and continued fertility, indicating as they do the value of manure, lime and a phosphate fertilizer.

THE NEW LONDON FIELD NO. 1, HENRY COUNTY

A second field experiment on the Grundy silt loam in Henry county was carried out on a farm two miles north of New London. The results of the experiment are given in table XVI. The experiment was started in 1914, the plots in this test being one-fifth of an acre in size. The yield of corn for the year 1914 is not given in the table, owing to the irregularities in the soil, which were much the same as those occurring in the Mt. Pleasant field. Again the yield of the untreated plot or check plot is determined by averaging plots 1, 7 and 13 and this average only is recorded in the table.

In a general way the results secured in this experiment confirm the indications observed in the experiment at Mt. Pleasant. The effect of the application of manure is much more evident, however, in this test, considerable increases in crop yields being noted each year. The application of lime increased the yields of every crop grown, showing a surprising effect upon corn and oats, as well as the expected effect upon clover.

The phosphate fertilizers in general increased the yields of all of the crops. There are some exceptions to this general rule, in a few instances no beneficial effects being secured either from the rock phosphate or the acid phosphate. The data in this experiment are hardly sufficient to warrant conclusions regarding the relative value of the two materials. In the livestock system plots, acid phos-

TABLE XVI. FIELD EXPERIMENT

New London Field No. 1. Grundy silt loam—Henry County*

Plot No.	Treatment	Oats bu. per acre 1915	Clover tons per acre 1916	Corn bu. per acre 1917	Corn bu. per acre 1919
1	Check (Av. of plots 1, 7 and 13)	58.3	2.2	50.0	51.5
2	Manure	63.6	2.9	61.7	52.9
3	Manure+Lime	69.2	3.0	64.8	55.2
4	Manure+Lime+Rock Phosphate	69.7	2.8	63.7	60.0
5	Manure+Lime+Acid Phosphate	72.0	2.8	68.6	64.0
6	Manure+Lime+Commercial Fertilizer	78.9	2.5	55.0	56.5
8	Crop Residues	64.2	1.9	47.7	50.1
9	Crop Residues+Lime	66.4	2.2	51.3	57.8
10	Crop Residues+Lime+Rock Phosphate	70.0	2.4	59.5	58.0
11	Crop Residues+Lime+Acid Phosphate	60.6	2.1	56.4	52.4
12	Crop Residues+Lime+Commercial Fertilizer	86.8	3.0	53.2	47.3

phate seemed somewhat superior, but on the crop residue plots there not only seemed to be no superior value, but the results were somewhat smaller than those secured from rock phosphate.

Again, it should be emphasized that the value of these two materials will depend very largely upon the cost, and the cheaper rock phosphate may actually prove more economical than the more quickly acting acid phosphate. These results, like the former, therefore, indicate the desirability of farmers testing the phosphate fertilizers on the Grundy silt loam and, by using the two materials mentioned, determining for their own conditions which is the more economical. The complete commercial fertilizer in one or two cases showed up a little better than the phosphate fertilizer, but in general it was not as effective in increasing crops as were the phosphate materials.

These results on this field confirm those obtained at Mt. Pleasant and, altho the data is not as definite as will be secured in the next few years, yet the indications point strongly to the value of the use of lime and phosphate fertilizers in making this soil more productive.

These field experiments as a whole indicate quite definitely that the Grundy silt loam, the main type in Wayne county, will respond profitably to applications of manure, lime, and phosphorus fertilizers. It is planned to establish some experimental fields in this county and thus check up on the results secured in Henry and Wapello counties. Several years must elapse, however, before the results from such tests would be sufficiently complete to permit of definite conclusions and positive recommendations. In the meantime it is urged that farmers test the value of phosphorus fertilizers on their own soils, using both rock phosphate and acid phosphate, and thus determine for their own conditions the relative value of these materials. The results given in the foregoing tables should be considered indicative only of what may occur in the field and farmers should test the various materials on small areas before making large applications. If the returns secured on a small area show profit from the application, over and above the cost of the material and of applying, then that material may be used on a large area with the assurance of profit.

*The yield of corn for 1918 was not secured.

THE NEEDS OF WAYNE COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD EXPERIMENTS

While no field experiments have been carried out in Wayne county, the results of the tests in Wapello and Henry counties on the Grundy silt loam, the main soil type in Wayne, permit of the drawing of some tentative conclusions regarding the needs of this soil in this county. Furthermore, the indications from these field tests are confirmed by the laboratory and greenhouse experiments on the soils obtained from Wayne county. While, therefore, it is not possible to make positive recommendations regarding the use of some fertilizing materials, there are indications from these results which point to the desirability of the adoption of certain methods of soil treatment in Wayne county which will lead to better crop production and a more desirable condition of the soil. It is hoped that field experiments may be conducted in this county and when this is done, more definite experimental data will be available than is the case at present. The suggestions which are made in the following pages are based upon the experiments reported and upon some farm experience and there is sufficient evidence to warrant the testing of certain materials which will be mentioned.

LIMING

All the soils in Wayne county have been found to be acid in reaction and the acidity in most instances is rather large. Not only do the surface soils show an acid condition, but the lower soil layers are likewise deficient in lime. This is true in the case of all the soils of the county with one exception. Crop growth, particularly of legumes, is well known to be less satisfactory on acid soils than on land which is properly limed. In fact, in many cases the presence of lime in soil may be the factor determining whether or not a profitable growth of a legume will occur. It is quite evident, therefore, that if crop production in Wayne county is to be increased and kept satisfactory, all the soils of the county should be tested for acidity and the necessary amount of lime applied. Farmers may test their own soils for lime requirement, but it will be more satisfactory if they will send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested more accurately free of charge. In this way it will be possible for them to apply the proper amount of lime and avoid the use of an insufficient amount or an excessive application, both of which are undesirable economically.

The results of the acidity determinations on representative samples of soil taken from the county have been given earlier in this report. They should be considered merely indicative. however, of the needs of the soils of the county and should not be taken to show the absolute amount of lime needed on any soil type. The lime requirement of soils is extremely variable and even the average results of several determinations will not show the need of lime on any particular soil. The soil of each individual field on the farm should be tested and only in this way can the proper amount of lime needed on that field be applied. Further information regarding the use of lime on soils, the losses by leaching and other points connected with liming are given in bulletin 151 of the Iowa Agricultural Experiment Station. Lists of limestone dealers and the cost of the material are given in circular 58.

MANURING

The soils of Wayne county are not strikingly deficient in organic matter, but neither are the more extensive upland types excessively supplied with this material. The Shelby loam is the lowest of any of the soil types in organic matter and it is one of the most extensive soils in the county. The application of humus-forming materials on this soil is particularly desirable. Farm manure provides the best means of supplying organic matter to soil and it gives large returns when used on this soil. It is found, however, that the other soils of the county, even tho better supplied with organic matter, will respond to applications of farm manure. The experiments both in the greenhouse and in the field show rather striking effects from the use of farm manure on the Grundy silt loam. Similar results have been secured on the Grundy clay loam. It seems evident, therefore, from these tests and from general farm experience that farm manure is the most valuable fertilizing material for use on the soils of the county and that this material should be applied in as large amounts as practicable.

The beneficial effects of manure when applied to soils are the result of its physical, chemical and bacteriological influences on soil conditions. Light, open soils are made more retentive of moisture, less open and porous and less subject to losses of plant food by leaching. Heavy, impervious soils are opened up and aerated, rendered less retentive of excessive moisture and put in a better condition in general for the production of available plant food. Much of the plant food removed from the soil by crops which have been fed on the farm may be returned to the soil by the proper use of manure. It brings about an actual increase in the content of plant food in the soil and thus has an important influence in lengthening the "life" of the soil. Manure also contains a large amount of organic matter and this material has an important effect on the physical and chemical condition of the soil. It also exerts a very pronounced influence on the bacterial conditions in the soil. Bacteria are present in manure in very large numbers and the application of this material increases the number of bacteria in the soil by the actual addition of the organisms. The organic matter supplied brings about a further increase and the result of the use of manure is to increase bacterial action to a very large extent and hence increase correspondingly the production of available plant food. In most instances manure probably benefits the soil because of the combination of physical, chemical, and bacteriological effects, but in some cases its value may be due to any one of these causes.

The value of manure in increasing crop production is so large that it is very important to protect it from deterioration before it is applied to the soil. Much of the value of manure may be lost if it is not properly stored. When kept in open piles, exposed to the weather and to the washing away of the liquid portion, 75 to 90 percent of its value may disappear. Various methods of storing manure have been suggested which will prevent such extreme losses and while no one methods can be recommended for all conditions, from among those suggested some method may be chosen which will be suitable under almost any farm conditions and will keep the manure as nearly as possible protected from serious losses. In general it may be said that manure should be kept moist and compact and protected from the weather if the losses are to be kept at the lowest point. When thus properly stored and applied to the soil, manure may return 75 to 90 percent of the valuable constituents removed from the soil by crops. It is apparent that any labor or expense involved in properly storing the material will, therefore, be well warranted by the value of the material on the soil.

The usual application of farm manure amounts to 8 to 10 tons per acre once in a rotation, and the amount of manure produced on the average farm is rarely sufficient for any larger application to all of the soils on the farm. In fact, in most cases the amount produced is not large enough for even this application. It is extremely unlikely, therefore, that excessive applications of manure would be made on the farm, but it may be said that for general farm crops, applications of more than 16 to 20 tons per acre are not considered advisable. Only in the case of market gardening or truck farming or where soils are strikingly deficient in organic matter is it desirable to increase the application over the amount normally used.

When the production of manure on the livestock farm is insufficient to permit of applications at regular intervals to all the soils of the farm, some other method of supplying organic matter to the soil must be chosen. On the grain farm where the production of manure is small, it is absolutely necessary that some means of supplying organic matter be chosen. Green manures are the best substitute for or supplement to farm manure and may often be used with profit under both systems of farming. Various crops may be used as green manures, but legumes are considered preferable because of their ability when well inoculated to fix the free nitrogen of the atmosphere. When turned under in the soil they increase the amount of this element in the soil and at the same time they increase the amount of organic matter present. Occasionally non-legumes may be preferred as green manure crops, but it is only under rather unusual conditions that legumes would not be more desirable. Many legumes are available for use as green manures and some one may be chosen which will fit in with almost any rotation. The practice of green manuring may prove a profitable one on some of the soils in Wayne county, especially where farm manure is available only in limited amounts. The practice should not be followed blindly or carelessly, however, for it may sometimes prove unprofitable or even injurious. Advice regarding this practice in special cases will be given by the Soils Section upon request.

Crop residues such as straw and stover are of considerable value in keeping up the organic matter supply in the soil. They are also of value because of the plant food which they contain and because of their effect in lengthening the "life" of the soil. They may also have an important effect on the physical condition of the soil. It is very desirable, therefore, that such materials be returned to the soil and not burned or otherwise destroyed as is too often the case. They may be used for feed or bedding on the livestock farm and returned to the soil with the manure. On the grain farm they may be applied to the soil directly or stored and allowed to partially decompose before application. It is particularly desirable to utilize crop residues on the grain farm, owing to the lack of farm manure, but it is also very desirable to return all these materials to the soil on the livestock farm.

THE USE OF COMMERCIAL FERTILIZERS

The soils of Wayne county are apparently rather low in phosphorus, according to the analyses given earlier in this report, and it would seem that phosphorus fertilizers might be employed on the soils of the county with profit. Evidently they will be needed in the near future, even if they do not prove of value at the present time. The indications from the greenhouse and field experiments, however, are that some phosphorus fertilizer may be used with profit in some cases at the present time. The data available at present is insufficient to warrant a general recommendation for the use of such materials, but it provides a basis for the recommendation that phosphorus fertilizers be tested on all the soils of the county.

Two forms of phosphorus fertilizers may be used, rock phosphate and acid phosphate. The latter contains the phosphorus in a more available form but it is much more expensive than the rock phosphate, while the latter material, altho considerably cheaper, must be applied in much larger amounts. It is still a question which of the two fertilizers can be used with the more economical returns and it is urged that individual farmers test these two materials under their particular conditions and determine not only the value of phosphorus on their own soils, but also the more desirable fertilizer containing this element which should be used. Simple tests of these materials may be carried out by any farmer with very little difficulty. Directions for such tests are given in circular 51 of the Iowa Agricultural Experiment Station and advice along this line will be given by the Soils Section upon request. The indications of value from the use of phosphorus fertilizers are so definite that the desirability of testing the materials on individual farms is strongly to be recommended.

The nitrogen supply in the soils of Wayne county is not very low, but neither is it excessive, and for the continued fertility of the soils of the county, some nitrogenous fertilizing material must be used. Nitrogen is lost from the soil by crop growth and leaching and the supply continually decreases. Crop residues and farm manure return considerable amounts of this element to the soil, but some other means of keeping up the supply is necessary in most cases. Leguminous crops used as green manures are the cheapest and most satisfactory nitrogenous fertilizers and the use of commercial nitrogen cannot be recommended at the present time for general use on the soils of the county. They may be employed in small amounts as top-dressings to stimulate the early growth of some crops or they may be employed profitably in market gardening, but they are too expensive for use on general farm crops. If they give profitable returns there is no objection to their use, but in general leguminous green manures provide nitrogen at a much lower cost and at the same time supply organic matter, so that they have a double value.

The use of potassium fertilizers on the soils of the county is probably quite unnecessary. Such large amounts of potassium are present in the soils of the county that fertilizers containing this constituent cannot be recommended for general use. If the soil is kept in the best physical condition with regard to air, moisture, and organic matter supply, available potassium may be produced in sufficient amounts from the store present in the soil to keep crops supplied and the use of fertilizers containing available potassium should not be necessary. They may be employed in small amounts as top dressings and may prove of value in market gardening, but for general farm crops, economical returns from their use are extremely unlikely.

The value of complete commercial fertilizers when applied to soils is dependent upon their content of the three plant food constituents, nitrogen, phosphorus and potassium. Inasmuch as nitrogen may be supplied more cheaply in leguminous green manure crops and potassium is present in soils in large amounts, it seems unlikely that complete fertilizers would prove as profitable on the soils of Wayne county as a phosphorus fertilizer, such as rock phosphate or acid phosphate. These latter materials are much less expensive and indications at the present time are that they will bring about quite as large crop increases as would the complete brands. There is no objection to the use of complete fertilizers and no injury to the soil is brought about by their application. The desirability of using them is merely a question of profit and particularly a question of relative profit secured when such materials are compared with acid phosphate or rock phosphate. Farmers who are interested in complete commercial fertilizers should test their value on a small area in comparison with phosphate materials and determine their relative value before making any extensive applications. The general use of complete fertilizers in Wayne county cannot be recommended at the present time, unless tests on a small scale have proved their value for particular conditions and particularly their superior value over the phosphorus carriers.

DRAINAGE

Wayne county in general possesses a rather extensive drainage system and the soils are not largely in need of artificial drainage. In some instances, however, the installation of tile would prove of considerable value. The Grundy clay loam and the Wabash clay loam are particularly in need of tiling, while many areas in the Grundy silt loam would also be benefited. The Calhoun silt loam may also be improved by drainage in some areas. Wherever the soil is too wet, crop production is low and the first treatment needed to make it satisfactory is the installation of tile. The expense involved in tiling may often be considerable, but the results secured more than warrant the outlay. Any of the soils of Wayne county which are poorly drained, particularly the Grundy clay loam, should be thoroly tiled out if they are to be made productive.

THE ROTATION OF CROPS

The continuous growng of any one crop has been shown by many experiments and much experience to be much less satisfactory than the use of a rotation. Even if the particular crop is of unusual value, it is still more profitable in the long run to follow some rotation. No special tests have been carried out in Wayne county to determine the most desirable rotations, but there are some which are being followed thruout the state with profit. From among these, the following are suggested, which may be quite suitable for use in this county. Modifications of these rotations may be made as desired and in fact almost any rotation may be employed if it includes a legume and the most profitable crops. It is very important, not only for the continuous production of the best crops, but also for the permanent fertility of the soil, that some rotation be practiced.

1. FOUR OR FIVE-YEAR ROTATION

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

2—FOUR-YEAR ROTATION WITH ALFALFA

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

3—THREE-YEAR ROTATION

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

THE PREVENTION OF EROSION

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

Slowly falling rain may be very largely absorbed by the soil, provided the latter is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, rain falling on it will, of course, wash over it and carry away large quantities to the detriment of the land.

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

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

In Wayne county erosion occurs to a considerable extent in the Shelby loam, rendering much of this type unsuitable for cultivation. Many gullies have been formed and are increasing in size. When this soil is to be cultivated, it is very necessary that it be so managed as to prevent erosion. There are many cases where the reclamation of badly washed areas would be very desirable.

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

EROSION DUE TO DEAD FURROWS

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

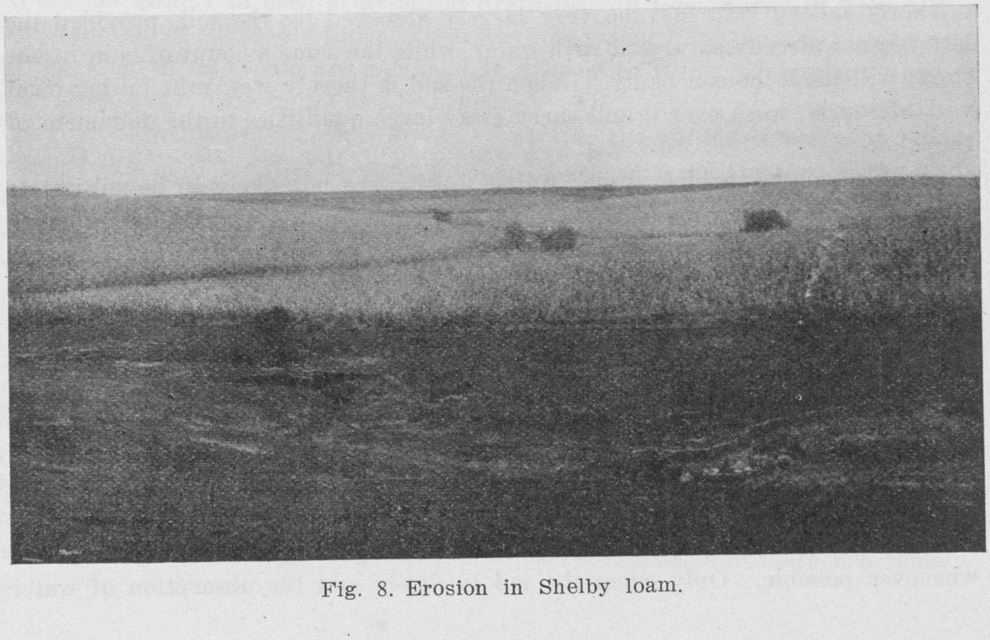

Fig. 8. Erosion in Shelby loam.

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

"Staking In." The method of "staking in" is better, as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three to four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point up-stream, 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. These are made somewhat higher than the surrounding land and act in much the same way as the stakes used in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be effective in preventing erosion in dead furrows.

SMALL GULLIES

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

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

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

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

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

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

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

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

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

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

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

LARGE GULLIES

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

BOTTOMLANDS

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

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

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

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter. Organic matter or humus is the most effective means of increasing the absorbing power of the soil, hence it proves very effective in preventing erosion. Farm manure may be used for this purpose, or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues, such as straw, corn stalks, etc., may also be turned under in soils to increase their organic matter content. In general, it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

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

Contour Discing. Discing around a hill instead of up and down the slope or at an angle to it, is frequently very effective in preventing erosion. This practice is called "contour discing" and has proved quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall-plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first, as the horses and disc, when turning, will pack and

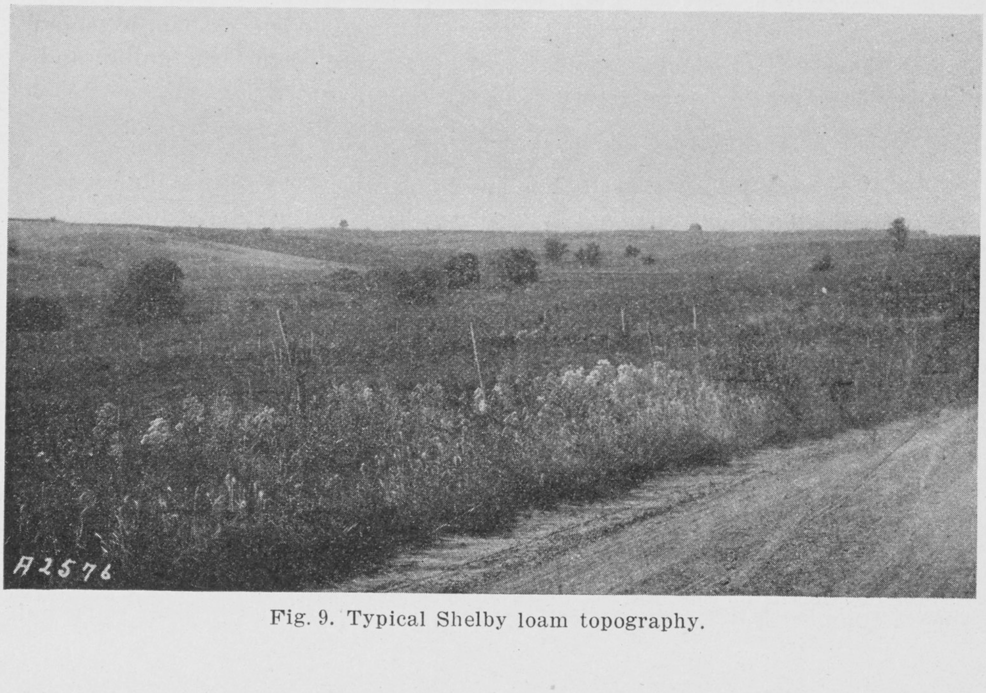

Fig. 9. Typical Shelby loam topography.

cover the center mark of the disc, thus leaving no depression to form a water channel.

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

DESCRIPTIONS OF INDIVIDUAL SOIL TYPES IN WAYNE COUNTY*

DRIFT SOIL

There is one drift soil in Wayne county, the Shelby loam, and it is one of the most extensive soils in the county, covering 153,024 acres, or 45.6 per cent of the total area.

SHELBY LOAM (79)

The Shelby loam occurs in all parts of the county, in association with the Grundy silt loam. It occurs on the slopes and the lower rounded and sloping ridges intermediate between the bottomland soil and the more level uplands occupied by the Grundy silt loam. Practically every slope bordering the steams is occupied by this soil type. Along the larger stream courses, the areas are broader and the largest development of the type is found along Caleb creek and the South Fork of the Chariton river. Other areas of considerable size occur along Locust creek and Big Fork Medicine creek in the southern part of the county. The belts of this soil along the streams become gradually narrower as the higher uplands are approached and in many cases the upper courses of the streams are bordered by very narrow strips of this soil. It is evident from its occurrence that the soil has been formed from the Kansan drift by a washing away of the loess covering. On the level uplands, where the loess has not been removed, the soils of the Grundy series are found.

The surface soil of the Shelby loam consists of about 10 inches of a dark brown loam or silty loam containing some sand. Below this point there is a brown, or dull brown, stiff, sandy clay loam, at lower depths becoming light brown to yellowish-brown, mottled with brown, yellow and gray. The subsoil contains considerable coarse gravel and glacial boulders. Boulders are also found occasionally in the surface soil, but they are seldom numerous enough to interfere seriously with cultivation. Along the lower slopes there is a variation from the typical soil, due to the fact that at those places the soil is deeper and represents an accumulation from the higher slopes. At these points the surface soil is a dark brown to nearly black loam to silty clay loam, extending to a depth of 10 to 18

*The descriptions of individual soil types given in the Bureau of Soils report have been closely followed in this section of the report.

inches. The underlying soil material is a dull brown to drab, more or less loamy sandy clay, mottled with brown, yellow-brown or gray in the lower part of the soil section.

In topography the Shelby loam varies from sloping to rolling and broken. In the southwestern part of the county along Caleb creek and its tributaries and on the slopes bordering the South Fork of the Chariton river, the rougher, more broken areas occur. Drainage is generally thoro and sometimes excessive. The soil is subject to erosion and on the steeper slopes, gullies which increase rapidly in size are of frequent occurrence. When cultivated it is very necessary that the soil be protected from washing.

About 50 percent of the type is cultivated; the remaining portion, which includes the rougher areas, is in permanent pasture or combined timber and pasture land. The forest growth on the wooded areas includes red oak, black oak, bur oak, white oak, hickory, elm, ash, and box elder, redhaw and hazel. In the cultivated portions the general farm crops are grown and include corn, oats, hay, wheat, rye, millet, sorghum, beans, potatoes and a few other minor crops. Corn yields from 25 to 60 bushels per acre, averaging 30 to 35 bushels; oats 20 to 50 bushels, averaging 35 to 40 bushels; wheat 15 to 20 bushels; and timothy and clover hay from 1 to 2 tons. The pastures are largely of bluegrass, with some white clover, and they are usually excellent. On this soil type the raising of livestock, mostly beef cattle, with hogs and some sheep, is the chief industry. In the smoother areas, crop growth is very much the same as on the level loessial areas of the Grundy silt loam, but in the rougher areas cultivation is more difficult and crop growth is somewhat less.

In general, the chief need of this soil type for better crop growth is protection from erosion. This injurious action is most evident, of course, in the rougher portions and there are undoubtedly areas where the soil should remain in pasture. Various means are available for protecting the soil from erosion and for reclaiming badly washed areas. These are considered in an earlier section of this report and from among the suggestions made, some method may be chosen which would be suitable for average conditions. When cultivated, this soil is particularly in need of organic matter and lime, and it will probably respond also to applications of phosphorus fertilizers. Farm manure has been found to bring about large increases in crop growth and should be used on this soil in as large amounts as practicable. The soil is acid in reaction and lime should be applied in proper amounts if the best crop growth, particularly of legumes, is to be secured. There are indications that phosphorus fertilizers may prove of value at the present time, and it is very desirable that these materials be tested on the individual farm. They will undoubtedly be needed in any case in the near future.

LOESS SOILS

There are two loess soils in the county, belonging in the Grundy series. These two types, together, cover 158,144 acres, or 47.1 percent of the total area. These soils, together with the Shelby loam, cover the entire upland of the county.

GRUNDY SILT LOAM (64)

The Grundy silt loam is the largest individual soil type in the county, covering 46.2 per cent of the total area. It occurs in all the level uplands and adjoining the Shelby loam, which borders the various streams. The areas of the Grundy silt loam vary considerably in size, many of them being rather narrow and others extending for several miles in width. The largest developments of this type are found in the northwestern corner, in the center of the county around Allerton and in the southeastern portion near Seymour.

The surface soil of the Grundy silt loam is a dark grayish-brown to nearly black silt loam extending to a depth of 8 to 10 inches. Below this point there is a lighter-colored mealy silt loam to silty clay loam, grayish-brown to brown in color and containing some yellow mottlings. At 18 to 20 inches there is a dense plastic clay, drab in color and mottled with brown, yellowish-brown and gray. The color of the soil becomes lighter in the lower depths and the mottlings more pronounced. The soil varies from the typical in some of the narrower strips by having a somewhat lighter color. In the southeastern part of the county on the flatter areas there is a variation from the typical soil, evidenced by the development of a gray subsurface layer about 6 inches in thickness. The surface soil and lower subsoil are very similar to the typical Grundy. This gray layer phase, if it were mapped separately, would be included with the Edina series, which has been recently established. The largest developments of this phase are found north of Harvard, between Harvard and Sewal, and in some small areas west and northwest of Seymour.

In topography the Grundy silt loam is almost level to gently undulating and in general the type is fairly well drained. On some of the more extensive flat areas, tile drainage is necessary in order to permit of the best crop growth.

Practically all of this soil type is improved and cultivated. Most of the general farm crops are grown, corn and oats being of the most importance. Wheat, rye, barley, millet and sorghum are also grown by many farmers and timothy and clover are important hay crops. Hog raising is practiced to some extent and some beef cattle and sheep are kept. These latter industries, however, are not as well established as on the Shelby areas. Corn yields from 35 to 75 bushels per acre, averaging about 50 bushels; oats, 30 to 65 bushels, averaging about 47 bushels; wheat, 15 to 30 bushels; and hay one to two tons. Yields of 10 to 12 bushels of timothy seed are sometimes secured, average yields being around 3 to 5 bushels per acre.

The Grundy silt loam is generally a rather productive soil, but its fertility can be improved by proper methods of treatment. It is acid in reaction and needs liming. It responds profitably to the application of farm manure and phosphorus fertilizers will probably prove of value. The greenhouse and field experiments discussed in earlier sections of this report indicate what may occur in the field from the use of these materials. It was found that farm manure brought about large increases in crop growth. Lime proved of value, particularly for legumes, and phosphorus fertilizers gave indications of profitable returns from their use. The results do not permit of the drawing of definite conclusions regarding the particular phosphorus fertilizer which should be employed and tests on individual farms, using both acid phosphate and rock phosphate, are strongly urged. It seems quite probable that in many cases one of these phosphorus carriers may be used on this soil type with profit at the present time and in all cases, phosphorus will be needed in the near future.

GRUNDY CLAY LOAM (68)

The Grundy clay loam, the second loess type in the county, is of very minor occurrence, covering less than 1 percent of the total area. It occurs in several small areas, the largest of which is around Humeston. Another considerable area is found just west of Seymour. Smaller areas occur near Bethlehem, New York and east of Cambria.

The surface soil of this type consists of 8 to 10 inches of dark brown to nearly black clay loam to silty clay loam. Below this point it becomes a dark brown or dark drab, dense, plastic silty clay containing some brown mottlings. At about 20 inches the color becomes lighter and the mottling more pronounced and at 30 inches the subsoil is a mottled yellowish-brown drab and gray heavy plastic clay. The subsoil is so very dense and compact that it is sometimes known locally as hard-pan. It is not true hard-pan, but causes some difficulty in cultivation. In untilled fields the surface soil is subject to cracking upon drying out and proper handling is necessary to prevent the occurrence of undesirable physical conditions which may interfere with satisfactory crop growth.

In topography the Grundy clay loam is level to depressed and the drainage is somewhat deficient. In many instances the chief need of this soil to make it more productive, is the installation of tile drains and the removal of the existing moisture.

Practically all of the type is under cultivation and in favorable seasons crop production is much the same as on the Grundy silt loam. The crops grown on this type are about the same as those grown on the silt loam. Corn is the leading crop, yielding 60 to 70 bushels per acre in favorable seasons. Under less favorable conditions the yields will average 35 to 40 bushels per acre. Oats yield 40 to 60 bushels per acre and wheat 20 to 25 bushels. Excellent yields of hay are usually obtained and pastures are good.

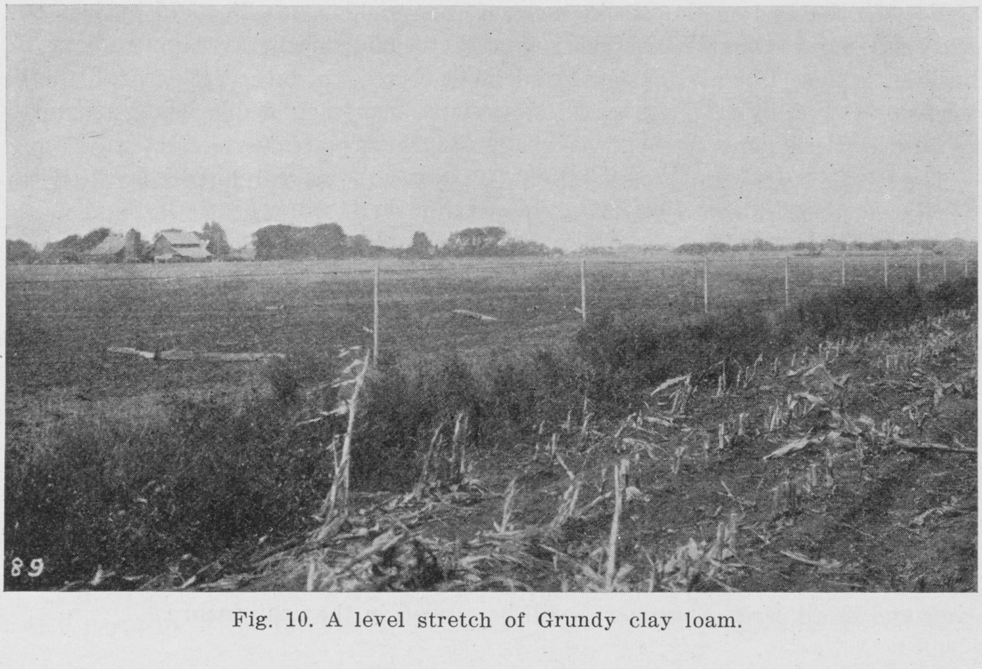

Fig. 10. A level stretch of Grundy clay loam.

The first treatment needed by most of the soil of this type to make it satisfactorily productive is adequate drainage. Otherwise crop growth is apt to be restricted, owing to unfavorable seasonal conditions. The soil must be plowed and cultivated carefully in order to put it in the best physical condition. Fall plowing is very desirable. The soil is acid in reaction and should be limed, especially for the best growth of clover. The need for lime is less evident on this type than in the case of the silt loam and necessary applications may be smaller than on that type. The soil will respond to applications of farm manure, even tho it is well supplied with organic matter. The addition of this material proves profitable probably because of the stimulation of bacterial action and the greater production of available plant food. Small applications of manure are perhaps most desirable for this soil. The use of clover or some other green manure will improve the physical condition. Phosphorus fertilizers will be needed in the near future and may prove profitable now.

TERRACE SOIL

There is one terrace type of very minor importance in the county, covering only 320 acres or 0.1 percent of the total area. It is classed as the Calhoun silt loam.

CALHOUN SILT LOAM (42)

The Calhoun silt loam occurs in a few small areas less than one-fourth of a mile in width, mainly along the south side of the South Fork of the Chariton river. It lies 20 to 30 feet above the first bottoms in a distinct terrace position.

The surface soil of the Calhoun silt loam is a brown to dark grayish-brown silt loam or silty loam 8 to 10 inches in depth. This is underlaid by a few inches of a white or light gray mealy silt loam, which becomes a little heavier with depth and contains faint mottlings of yellow or dull yellow. At 18 to 20 inches the subsoil becomes a dense, plastic clay, dull drab in color and mottled with yellow, grayish-brown and black, the color becoming somewhat lighter at the lower depths. Variations from the typical soil occur frequently along the outer edges of the terraces where considerable sand is present.

In topography the soil is almost level and the drainage is fair. It would undoubtedly be benefited in some cases by the installation of tile. Practically all of the soil is cultivated and the usual farm crops are grown quite successfully. It would be benefited, however, by certain treatments and crop production might be increased. It is acid and in need of lime. Its organic matter supply is not high and farm manure would prove valuable. It would probably also respond to applications of phosphorus fertilizers.

SWAMP AND BOTTOMLAND SOILS

There are two swamp and bottomland soils in Wayne county, both belonging in the Wabash series. Together they cover an area of 23,872 acres or 7.2 percent of the total area.

WABASH SILT LOAM (26)

The Wabash silt loam is the largest bottomland type, covering 18,624 acres or 5.6 percent of the total area. It occurs along all the principal streams except in parts of the bottoms of the South Fork of the Chariton river and Caleb creek, which are occupied by the Wabash clay loam. It is found in narrow strips in all cases, rarely exceeding one-fourth of a mile in width.

The surface soil of the Wabash silt loam is a dark grayish-brown to dark brown smooth friable silt loam to a depth of about 10 inches. Below this point the soil is somewhat lighter in color, gradually becoming heavier in texture with increasing depth. Between 10 and 20 inches the color is usually a grayish-brown, below 20 inches becoming a dark drab silty clay loam or silty clay mottled with gray and grayish-brown.

In many areas the soil varies considerably in color and texture. In the narrower bottoms it is often lighter colored than in the wider bottoms and the soil adjacent to the stream channels is lighter in texture than that further back. The subsoil frequently is a dark brown to black silt loam and in some of the wider bottoms back from the stream channels, below 20 to 24 inches, it is a heavy plastic dark drab silty clay. Along many of the smaller streams the type has been modified considerably by wash from the upland and the soil in these areas is very similar to what in other counties is known as the colluvial phase of the Wabash silt loam. This variation consists of a dark brown to black loam or silty loam to clay loam, overlying a drab or grayish-brown silty loam or clay loam mottled with brown and light gray. Along the South Fork of the Chariton river in Section 1 of South Fork township and in Section 36 of Wright township, there is an area of 80 to 90 acres where the soil is a light brown to grayish-brown fine sandy loam, 10 to 12 inches in depth, overlying a compact fine sandy loam, grayish to yellowish-brown in color. The soil in this area is really the Genesee fine sandy loam, but it is not separated on account of its small extent.

In topography the Wabash silt loam is nearly level or flat, with a gentle slope toward the streams. In some areas the surface is slightly billowy, due to abandoned stream channels, and in other places the surface is gently sloping. The drainage is fair, but the soil is subject to overflow. The straightening of stream channels and the opening of ditches has improved the drainage condition of the type and reduced the liability to overflow.

The Wabash silt loam is not used extensively for cultivated crops, most of the type remaining in pasture, in connection with the adjoining areas of Shelby loam. The timber growth consists mainly of elm, hickory, black walnut, willow, ash and some oak. Some of the wider, better-drained bottoms are in cultivation and the soils in these areas are quite productive. Corn is the most important crop grown on these areas, yields of 35 to 70 bushels being secured. The average yield of corn amounts to about 45 bushels per acre. Oats are grown to a small extent, yielding 25 to 50 bushels, and wheat, which is also of minor importance, yields 15 to 20 bushels. Timothy and clover yield fairly well in favorable locations. Blue grass and white clover furnish satisfactory pasture.

This soil is rather productive when properly drained and protected from overflow and crop yields under favorable conditions are quite satisfactory. When cultivated it would be benefited by the application of lime, as it is usually acid in reaction. Small applications of manure would also prove of value by stimulating the production of available plant food. Phosphorus fertilizers will be needed in the future and might show beneficial effects at the present time. The chief need of this soil, however, is for adequate drainage and cultivation.

WABASH CLAY LOAM (56)

The Wabash clay loam is much less extensive in Wayne county than is the silt loam. It covers 5,248 acres or 1.6 percent of the total area. It occurs in the wider bottoms of the larger streams, the largest areas being found along the South Fork of the Chariton river and lower Jackson creek. Other areas are found in the bottoms of the North Fork of the Chariton river in the northeastern corner of the county, and along Caleb creek. Small areas are also found along the Big Fork of the Medicine river and along Locust creek. In some of these areas the type occupies the entire bottom, while in others it is found back from the stream courses.

The surface soil of the Wabash clay loam consists of a dark brown to nearly black clay loam or loamy silty clay, extending to a depth of 6 to 10 inches. Below this point there is a gradual change to nearly black or dark drab dense plastic clay slightly mottled. Below 30 inches the color becomes somewhat lighter and the mottlings of yellow and brown quite pronounced.

In topography this type is nearly level or slightly depressed. The soil is poorly drained and water often stands on it for considerable periods. It is rather impervious and difficult to till and because of this is known locally as "gumbo." The term "gumbo" is not a recognized name for a particular class of soils, according to any accepted scheme of soil classification. It is a popular name for a group of soils which possess characteristics well known and dreaded by farmers. It is very different from the gumbo referred to in geological reports, which includes almost impervious gray or yellow clay subsurface soils. The soil that Iowa farmers call "gumbo," is a heavy, "greasy," black clay soil, occurring in flat areas, either river bottoms or level uplands. It is usually inky black and is stickier and bakes more easily than any other type of soil in the state. If such soil is plowed when too wet, it balls up before the plow point in such a way that the implement cannot be made to stay in the ground. On the other hand, if it becomes too dry, it will turn up in clods which cannot be worked down during the whole season. Where such clods are formed, freezing and thawing is the only process which will restore the loose, mealy structure. This soil can, however, be put into excellent tilth, with a fine, mealy appearance, and kept so during the entire season, provided it is not cultivated when too wet.

The Wabash clay loam is bottomland "gumbo" and while the entire area of the type is not typical "gumbo," it is all heavy and impervious in the subsoil and must be carefully handled when cultivated.

Owing to the poor drainage and difficulty of cultivation, much of this soil is in pasture and only the better situated areas are cultivated. The tree growth on the uncultivated areas consists of walnut, elm, willow, and other species of trees. Corn is the leading crop grown on the cultivated portion and in favorable seasons quite satisfactory yields are secured. Oats and wheat yield fairly well, but are apt to lodge. Bluegrass produces excellent pasture and in many areas the native grasses are used for pasture.

The soil is naturally productive and is chiefly in need of drainage and proper tillage to make it produce satisfactory crops. Tile should be laid 8 or 10 rods apart to secure thoro drainage. Those areas subject to overflow should be protected from this action if good crop growth is to be insured. This soil may be readily brought under cultivation by drainage, but the time and manner of plowing are important factors in preparing the seed-bed. Fall plowing would be desirable. The use of clover or some other green manure also improves the physical condition of the soil. The soil is acid in reaction and should be limed. A small amount of farm manure would prove of value on newly-drained areas. Phosphorus fertilizers will be needed in the near future if this soil is heavily cropped.

APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

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

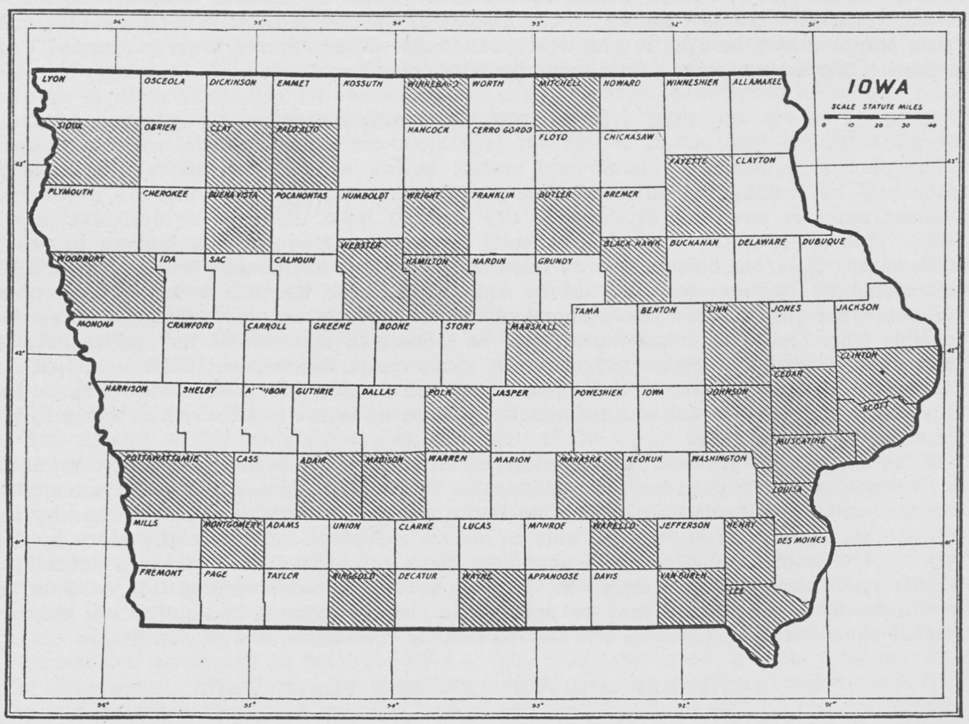

Fig. 11. Map of Iowa showing the counties surveyed January, 1921.

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

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

PLANT FOOD IN SOILS

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

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, 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.

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

THE " SOIL DERIVED" ELEMENTS

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

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

AVAILABLE AND UNAVAILABLE PLANT FOOD

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

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

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

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

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

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

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

REMOVAL OF PLANT FOOD BY CROPS

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

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

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

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

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO_3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nitrog'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
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	1.52	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

kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

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

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

REMOVAL FROM IOWA SOILS

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

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

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

PERMANENT FERTILITY IN IOWA SOILS

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

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

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

CULTIVATION AND DRAINAGE

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

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

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of 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.

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

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

THE ROTATION OF CROPS

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

*Bulletin 150, Iowa Agricultural Experiment Station.

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

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

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

But, whatever the reason for the bad effect 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.

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

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

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

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating materials that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

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

THE USE OF PHOSPHORUS

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

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

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

LIMING

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

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

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 12.

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

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till' 'or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift soil was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

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

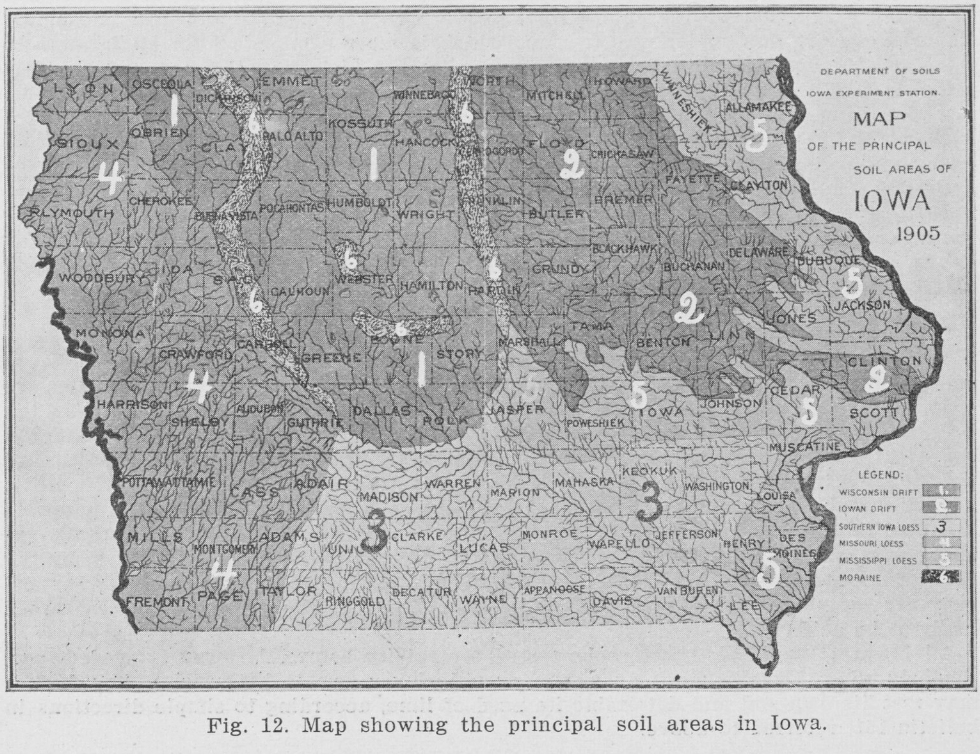

Fig. 12. Map showing the principal soil areas in Iowa.

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

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by 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.

GENERAL SOIL CHARACTERISTICS

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

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

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 or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
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 undecomposed 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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Gravels—More than 50 percent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

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

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

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 srteam, 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 tabel. The character of the soil types is ascertained in the section by the use of the auger, an instrumnt for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

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

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

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

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