SOIL SURVEY OF IOWA

LINN COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 17
December, 1920
Ames, Iowa

IOWA AGRICULTURAL EXPERIMENT STATION

PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA

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SOIL SURVEY OF IOWA

Report No. 17---LINN COUNTY

By W. H. Stevenson and P. E. Brown, with the assistance of T. H. Benton and F. B. Howe

Carrington silt loam southeast of Center Point. The background shows Clinton silt loam

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

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LINN COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of T. H. Benton and F. B. Howe

Linn county is located in east central Iowa in the third tier of counties west of the Mississippi river. It is bordered by Benton county on the west, Johnson on the south, Jones on the east and Buchanan and Delaware on the north. It is partly in the Iowan drift soil area and partly in the Mississippi loess area. Its upland soils are therefore partly glacial in character and partly loessial, the larger area being covered by the drift soils.

The total area of the county is 709 square miles, or 453,760 acres. Of this area, 383,711 acres, or 84.5 percent, is in farm land. The total number of farms is 3,041 and the average size is 126.2 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	240,200
Acreage in pasture	119,395
Acreage in farm buildings, feed lots, and highways	15,828
Acreage in waste land	4,418
Acreage in crops not otherwise listed	1,181

General farming is practiced most extensively in Linn county and the raising and feeding of hogs and cattle are important industries on many farms. In some sections the livestock industry is of major importance, the farm products being used chiefly for the feeding of cattle and hogs. Trucking is practiced in the sandy areas near Cedar Rapids and in 1917, 1,359 acres were reported in garden crops. Some fruit is grown on most farms, but there are no commercial orchards. Besides the general farm crops, sweet corn and pop corn are grown to some extent.

The area in waste land is rather large and it is quite desirable that some method of soil treatment be practiced to reclaim such land. The causes of infertility are varied and hence no general recommendations can be made for treatment. In the discussion of individual soil types given later in this report, methods are suggested which should be followed in reclaiming waste areas. 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 Linn county in the order of their importance are corn, oats, hay, wheat, barley, potatoes, rye, and alfalfa. The acreage, yields, and value of these crops in the county are given in table 1.

Corn is the most important crop, covering by far the largest acreage and representing a value considerably greater than that of any other of the general farm crops grown. The average yield of corn for the county is 37.2 bushels per acre. A large part of the crop produced is fed on the farms, but a con-

*See Soil Survey of Linn county by F. B. Howe and T. H. Benton of the Iowa Agricultural Experiment Station and M. Y. Longacre and A. H. Meyer of the United States Department of Agriculture.

TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN LINN COUNTY

Crop	Acres	Percent of total farm land in the county	Bu. or tons per acre	Total bushels or tons	Average price	Total value of crop
Corn	112,088	29.2	27.2	4,173,359	$ 1.23	$5,133,231
Oats	67,845	17.6	45.2	3,064,252	.64	1,961,121
Winter wheat	364	.09	16.3	5,935	1.99	11,810
Spring wheat	5,598	1.46	19.3	108,161	2.02	218,485
Barley	5,638	1.47	31.1	175,406	.89	156,111
Rye	1,190	.31	12.6	15,056	1.48	22,282
Hay (tame)	42,966	11.2	1.2	50,798	19.57	994,116
Hay (wild)	2,667	.69	1.1	2,890	16.00	46,240
Alfalfa	136	.03	....	367	23.93	8,782
Potatoes	1,708	.44	60.8	103,881	1.32	137,122
Pasture	119,395	31.11	....	....	....	....

siderable amount is sold, particularly from the tenant farms. There is a large number of silos and much of the corn is used for ensilage.

Oats rank next to corn, both in acreage and value. Average yields amount to 45.2 bushels per acre and in favorable seasons, the yields on many farms are much higher than this average. Much of the oats is fed on farms, altho a large quantity is sold.

The hay crop consists mainly of the tame grasses, only a comparatively small area being devoted to wild hay. Timothy and clover mixed furnish the chief tame hay crop, average yields of 1.2 tons per acre being secured. Millet is grown to a small extent. Some clover is grown for seed and timothy is also occasionally grown for seed, but in general these crops are used mainly for hay. A large part of the hay produced is used for feeding purposes, but some is sold off the farms.

Wheat is an important crop, ranking next to hay in total value. Spring wheat is grown most extensively, only a comparatively small acreage being in winter wheat. Winter wheat is grown to some extent on light, sandy soils and serves to prevent washing and blowing of the soils during the winter and spring months. Average yields of the spring varieties amount to 19.3 bushels per acre, while winter wheat yields 16.3 bushels per acre.

Barley is grown on a rather large area and the value of the crop is considerable. Potatoes are grown to some extent, average yields of 60.8 bushels per acre being secured. Rye is produced on a small area, but is a relatively unimportant crop.

Alfalfa is grown on a very small area, but where proper precautions have been taken in preparing for this crop, yields have been very satisfactory. There is no reason why alfalfa should not prove very profitable in the county.

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

Horses (all ages)	17,456
Mules (all ages)	662
Swine (on farms July 1, 1918)	154,996
Cattle (cows and heifers kept for milk)	16,373
Cattle (other cattle not kept for milk)	36,669
Cattle (total all ages)	54,042
Sheep (all ages on farms)	9,522
Sheep (total pounds of wool clipped)	41,685

Livestock raising is a very important industry and the sale of hogs and cattle brings in a large part of the income on many farms. The cattle are mainly Shorthorns, altho there are some herds of Herefords and of Angus. Dairying is an important industry and there are several Jersey and Holstein dairy herds. Hog raising is practiced very extensively and large numbers are marketed annually. Duroc Jerseys, Chester Whites, and Poland Chinas are the chief breeds. Many horses and mules are raised, the horses being nearly all of the draft type. Sheep are kept on a few farms and the value of the wool produced is considerable. Poultry raising is not practiced as a separate industry, but practically every farmer raises sufficient poultry to supply the home demand and permit of some sales.

Land values in Linn county are extremely variable, depending upon the improvements, the character of the soil and the location with reference to towns and railroads. The selling price ranges from $75 to $500 per acre, averaging $225.

The soils of Linn county are in general fairly productive and in many cases quite satisfactory crop yields are produced without the observance of special methods of soil treatment. In many of the soil types, however, the natural fertility is rather low and crop production is not satisfactory. The yields on these types may be increased and the soils may be brought up to a higher state of fertility by following proper methods of treatment. It is essential that all of the soils of the county be managed properly if crop production is to be made and kept satisfactory.

Practically all of the soils of Linn county are acid and in need of applications of lime. In many cases, the acidity is great and the need of lime very pronounced. Every soil in the county should therefore be tested for its reaction and the necessary amount of lime applied. Crop production, particularly of legumes, will not be satisfactory unless the soils are well supplied with lime.

Applications of farm manure are needed on practically all the soils. Even those types which are not particularly deficient in organic matter will respond to the use of this material and it should be applied in as large amounts as practicable. On many of the soils, the organic matter supply is very low and the application of farm manure is particularly necessary. When the production of farm manure is insufficient to provide for all of the soils on the farm, leguminous crops should be used as green manures. They will serve to keep up the supply of organic matter and also aid in maintaining the nitrogen content. The latter element is not particularly deficient in most cases, but it will need to be supplied at regular intervals if the nitrogen content of the soil is to be kept up. Where the supply of nitrogen is low, the use of legumes as green manures is especially recommended.

The phosphorus content of the soils of the county is rather low and phosphate fertilizers will undoubtedly be needed in the near future, if they do not prove of value now. There are indications from the field and greenhouse experiments that such materials may be used with profit in many cases at the present time. The use of complete commercial fertilizers will probably prove less profitable than phosphorus carriers on most of these soils, but if tests indicate that they will prove valuable, they may be used without fear of injury to the soil. Definite recommendations cannot now be made regarding the particular phosphate fertilizer which should be used, but farmers are urged to test both rock phosphate and acid phosphate on their own farms and determine for their own conditions which material will prove the more profitable.

Some of the soil types in the county are in need of drainage and the installation of tile is the first treatment needed to bring such soils up to the proper state of fertility. No other soil treatment will be of any large value on soils which are too wet. While the installation of tile may be somewhat expensive, it always proves profitable. The proper rotation of crops, the thoro cultivation of the soil and the careful return of all crop residues, are other methods of soil treatment which are very necessary in improving and maintaining the fertility of Linn county soils.

THE GEOLOGY OF LINN COUNTY*

The rock formations underlying the soils of Linn county are buried so deeply under the deposits of drift and loess that they exert no influence whatever upon the character of the soils. The geological study of these rocks is, therefore, of no practical significance and need not be considered here.

Twice during the glacial age, great ice sheets swept across the county from the north and upon their retreat left behind vast deposits of glacial material known as drift or till. These deposits were composed of a wide variety of materials gathered up by the great ice sheets in their forward movement over the land, and as the material was secured from many rock formations, it is extremely variable in mineral content. The older drift sheet, known as the Kansan, was covered by the later deposit, the Iowan, and is exposed only in the deeper stream channels. The drift soils of the county are very largely derived from the Iowan drift and only in a comparatively small portion is the effect of the Kansan till evident. This older drift is usually a blue clay mixed with much other material, such as quartz grains, pebbles and boulders. Occasionally pockets of sand and gravel occur and layers of these materials are also found. None of these are near enough to the surface, however, to exert any particular effect upon the soil conditions.

The Iowan drift is typically a bluish-gray or drab clay to sandy clay, also containing pockets or beds of sand and gravel. The thickness of this drift layer is extremely variable, ranging from a few feet to over 100 feet in depth, being somewhat thinner in the Wapsipinicon than in the Cedar Valley. Pebbles and boulders are found thruout the soils derived from this till, the larger number appearing in the subsoil. Under the process of weathering, the character of the deposit has been considerably modified and the clay has been weathered to a yellow or brown color. The lime content, which was originally considerable, has been very largely leached away and the soils are now generally distinctly acid. There has been a considerable washing away also of much of the soluble constituents and the composition of the surface soil is quite different from that of the underlying material. The accumulation of organic matter from the

*Iowa Geological Survey. Volume IV.

vegetation residues has imparted to the surface soil a dark brown to black color in many places. Where the area has been timbered, the accumulation of organic matter has been much less and the soils are lighter in color. The subsoils of these areas, however, are very little different from those of the darker colored types.

At some period following the glacial age, a deposit of fine, wind-blown material known as loess, was made over the surface of a portion of the county, but no extensive continuous areas of this loess are found. The soils derived from it occur mainly in the valley of the Cedar river, altho there are considerable areas also along the Wapsipinicon. It is typically a brownish-yellow to light gray silty material, the surface of which, under the process of weathering and the accumulation of organic matter, has been changed to a dark brown to black in color, at least in the case of the prairie soils. In the timbered loess area the color has been little changed and is typically dark gray to light grayish-brown. In general this loess deposit is little more than 3 feet in depth and in many places it is very shallow, giving rise to the soils of the Lindley series, which possess many of the drift characteristics, especially below the surface. The leaching of the loess types has been less extensive than in the older drift soils, but the removal of lime has been almost complete and these soils also are generally acid in reaction.

PHYSIOGRAPHY AND DRAINAGE

The topography of Linn county is in general gently rolling, with a slope towards the southeast. This is particularly true of the central portion of the area, between the Wapsipinicon and Cedar rivers. In some areas, the land is almost flat, as, for example, where the soils of the Clyde series are mapped. Along the valleys of the larger streams, there are typical, rounded, glacial hills and long ridges. Many of these ridges are covered with a thin layer of loess deposits. These hills have been called ''paha'' and there are many theories as to the manner of their formation. Along the Cedar river these ''paha'' ridges and hills occur chiefly to the north, altho some are also found south of the river. These rounded hills are found on both sides of the Wapsipinicon, reaching their greatest height near Waubeek.

Along the larger streams, there are many alluvial plains one to two miles in width but, in some instances, the upland loess ridges border the streams, which pass thru narrow, deep gorges. The topography near the streams is in many cases, therefore, quite rugged.

The drainage, with the exception of a small area in the southwestern part of the county, is brought about by the Cedar river, the Wapsipinicon river and Buffalo creek. These streams all cross the county from northwest to southeast and are almost parallel. By far the larger area is drained by the Cedar river and its tributaries, the largest of which are Otter creek, Dry creek, Indian creek, Apple creek and Abbey creek. The drainage basin of this river is not wide and there are no extensive areas of bottomland. The central portion of the county, which is drained by the tributaries of the Cedar, contains some areas where drainage is poor and the installation of tile would be highly desirable. This is particularly noticeable in Spring Grove and Otter Creek townships.

The areas drained by the Wapsipinicon river and Buffalo creek are relatively narrow and there are no large tributaries. The valley of the Wapsipinicon is narrow, but some alluvial soils are found along this stream, particularly near Troy Mills and Central City. Buffalo Creek is fed by a few small, sluggish streams from the northeast and with these tributaries, drains the northeastern corner of the county. Several rather large areas of alluvial soil are found along this stream, but in general it is bordered by the steep slopes of the loess upland.

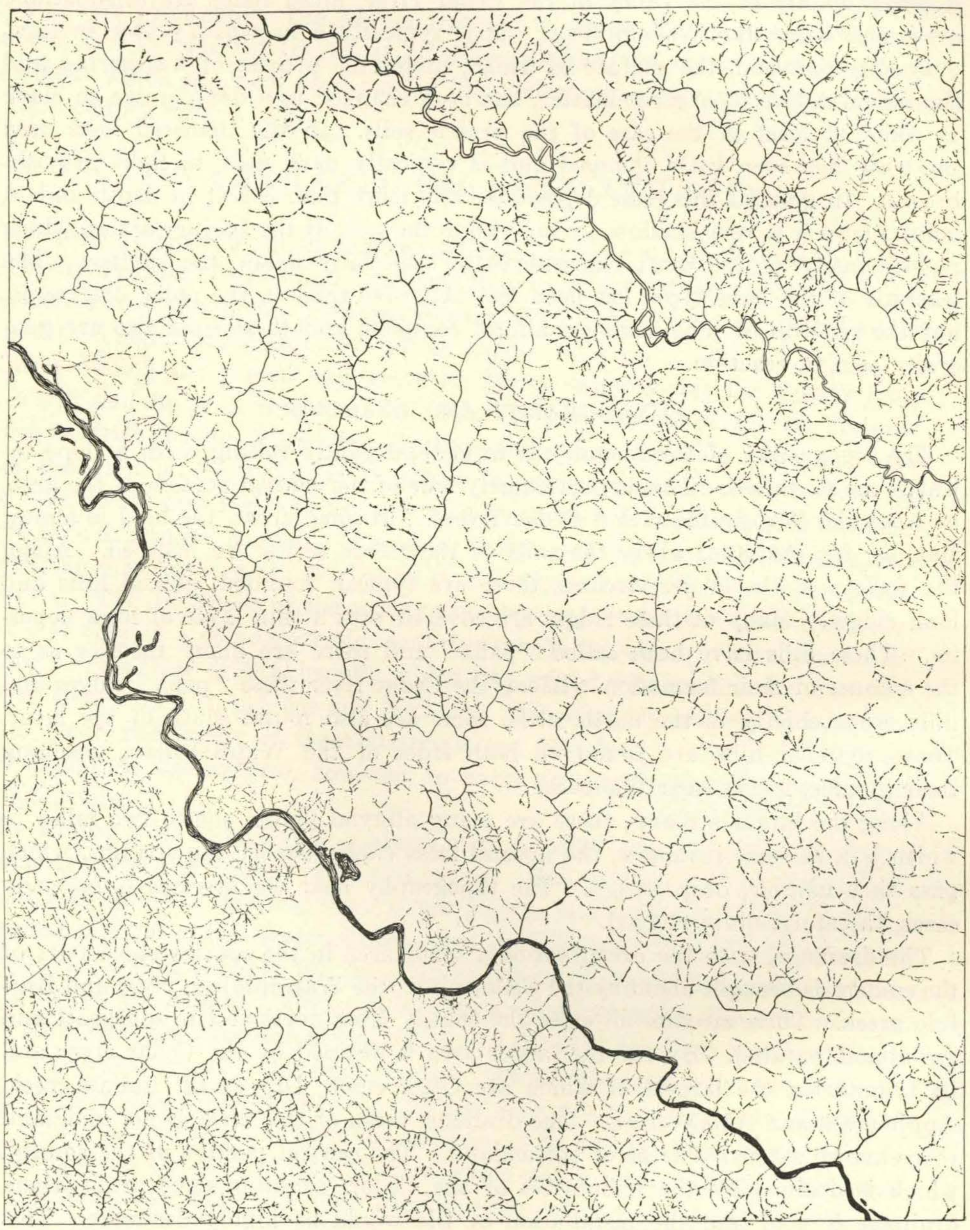


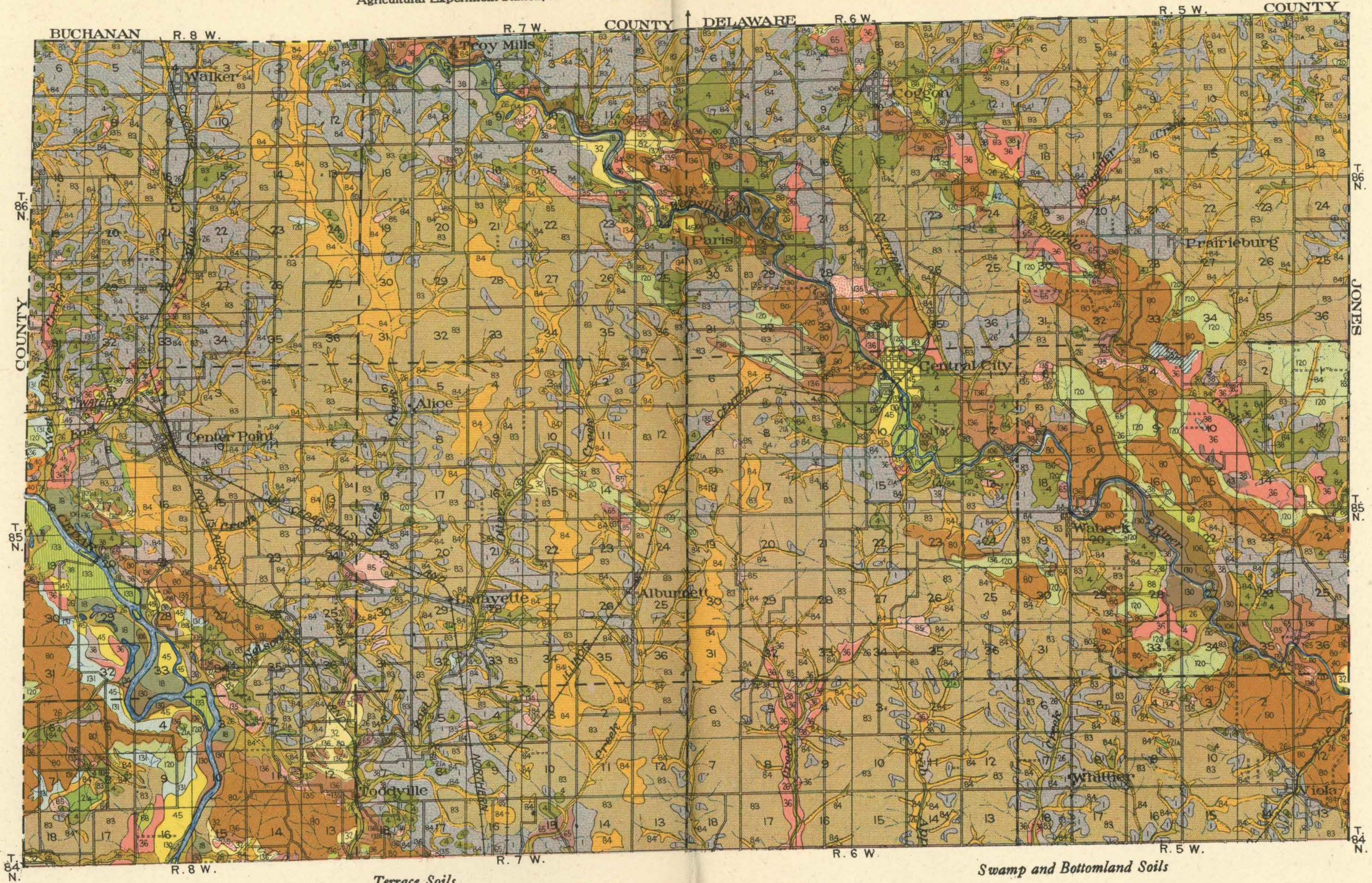
Fig. 1. Natural drainage system of Linn county

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

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

UPPER HALF

Thomas D. Rice, Inspector Northern Division-Soils surveyed by F. B. Howe in charge and T. H. Benton of the Iowa Agricultural Experiment Station, M. Y. Longacre and A. H. Meyer of the U. S. Department of Agriculture.



LEGEND

Drift Soils

- 4 Carrington fine sandy loam
- 134 Carrington very fine sandy loam
- 1 Carrington loam
- 83 Carrington silt loam
- 84 Clyde silt loam
- 85 Clyde silty clay loam

Terrace Soils

- 42 Calhoun silt loam
- 88 Bremer silt loam
- 43 Bremer silty clay loam
- 40 Buckner sandy loam
- 45 Buckner fine sandy loam
- 38 Buckner loam
- 36 Buckner silt loam
- 131 Judson silt loam
- 132 Judson silt loam (light colored phase)

Swamp and Bottomland Soils

- 130 Cass fine sandy loam
- 18 Cass loam
- 106 Cass silt loam
- 133 Sarpy fine sand
- 21A Muck
- 26 Wabash silt loam

LEGEND

Loess Soils

- 135 Lindley fine sand
- 136 Lindley fine sandy loam
- 137 Lindley very fine sandy loam
- 65 Lindley loam
- 32 Lindley silt loam
- 80 Clinton silt loam
- 120 Tama silt loam

Scale: 1 Inch 2½ Miles

IDLAND MAP AND ENGINEERING CO.
DES MOINES, IOWA

The accompanying map shows the drainage of the county and it is evident that only some of the areas in the central drift plain are in need of artificial drainage.

THE SOILS OF LINN COUNTY

There are four groups of soils in Linn county, known as drift soils, loess soils, terrace soils, and swamp and bottomland soils. The individual soil types are grouped into these classes on the basis of their origin and location. Drift soils are those which are deposited by glaciers upon their retreat and contain material 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 decrease in the volume of the streams by which they were formed, or by a deepening of the river channels. Swamp and bottomland soils are those occurring in low, poorly-drained areas or along streams subject to more or less frequent overflow.

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

By far the largest part of the county, over 69 percent, is covered by the drift soils. The loess soils are second in extent, covering 18.1 percent. The terrace soils and the swamp and bottomland soils are much less extensive, covering 6.4 and 5.9 percent, respectively.

The loess and drift soils which make up the upland, range from level in topography to rolling or even rough. Some small areas are level to flat, but the general topography is gently rolling. The rougher areas along the streams are sometimes too steep for cultivation, but the total area of such land is not large and many of these steeper areas provide excellent pasture. The terrace soils are level in topography and many of them are very productive. In a few instances, these terrace types are in need of artificial drainage. The bottomland soils are all level and subject to overflow. Some of them are in need of drainage, but more often they are in need of protection from overflow. The upland soils are generally well drained, but in some instances, such as the flat areas mentioned above, artificial drainage is necessary.

There are twenty six distinct soil types in Linn county and these, with the light colored phase of the Judson silt loam and the area of muck, make up twenty-eight separate soil areas. There are six drift soils, seven loess soils, nine terrace types and six areas of swamp and bottomland soils. The individual soil types in these groups are distinguished on the basis of certain characteritics which are discussed in the appendix to this report and the type names which are employed denote group characteristics. The areas of these soil types and the

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

Soil groups	Acres	Percent of total area of county
Drift soils	316,224	69.6
Loess soils	82,176	18.1
Terrace soils	28,928	6.4
Swamp and bottomland soils	26,432	5.9

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN LINN COUNTY

oil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
3	Carrington silt loam	225,664	49.7
1	Carrington loam	45,504	10.0
4	Clyde silt loam	31,680	7.0
4	Carrington fine sandy loam	11,776	2.6
5	Clyde silty clay loam	1,024	0.2
4	Carrington very fine sandy loam	576	0.1
	LOESS SOILS		
0	Clinton silt loam	40,128	8.8
0	Tama silt loam	15,552	3.4
2	Lindley silt loam	10,176	2.2
6	Lindley fine sandy loam	9,344	2.1
5	Lindley loam	3,264	0.7
5	Lindley fine sand	2,112	0.5
7	Lindley very fine sandy loam	1,600	0.4
	TERRACE SOILS		
6	Buckner silt loam	9,536	2.1
8	Bremer silt loam	4,928	1.0
1	Judson silt loam	3,712)	
2	Judson silt loam (light colored phase)	512)	0.9
8	Buckner loam	3,968	0.9
5	Buckner fine sandy loam	3,712	0.8
0	Buckner sandy loam	1,216	0.3
3	Bremer silty clay loam	1,152	0.3
2	Calhoun silt loam	192	0.1
	SWAMP AND BOTTOMLAND SOILS		
6	Wabash silt loam	15,808	3.5
8	Cass loam	3,520	0.8
6	Cass silt loam	2,752	0.6
0	Cass fine sandy loam	2,688	0.6
3	Sarpy fine sand	1,280	0.3
1a	Muck	384	0.1

ercent of the total area of the county covered by each type are shown in table II.

The drift soils are classed in the Carrington and Clyde series. The Carring-n silt loam is by far the most extensive drift soil, covering almost 50 percent f the total area of the county. It is not only the largest drift type, but by ır the largest individual type in the county. The Carrington loam is the econd largest drift soil, covering 10 percent of the total area and is the second ıost extensive type in the county. The Clyde silt loam and the Carrington fine ındy loam are still smaller in extent. The Clyde silty clay loam and the Car-ington very fine sandy loam, the two remaining drift types, are both of very ıinor importance.

The loess soils are classed in the Clinton, Tama, and Lindley series. The linton silt loam is the largest loess type and is the third type in size in the ounty, covering 8.8 percent of the total area. The Tama silt loam, the indley silt loam and the Lindley fine sandy loam are much smaller in extent, hile the three remaining loess soils, the Lindley loam, the Lindley fine sand and e Lindley very fine sandy loam, are all minor in extent.

The terrace soils are grouped in the Buckner, Bremer, Judson and Calhoun series, and none of the types is of any considerable extent. The Buckner silt loam is the largest, covering 2.1 percent of the total area of the county, and the Bremer silt loam is second, covering 1 percent.

The swamp and bottomland soils are classed in the Wabash, Cass and Sarpy series and there is a small area of muck. The Wabash silt loam is the largest bottomland type, covering 3.5 percent of the county.The Cass loam, the Cass silt loam and the Cass fine sandy loam are all much smaller in extent. The areas of Sarpy fine sand and muck are very small.

THE FERTILITY IN LINN COUNTY SOILS

Samples were taken for analysis from each of the soil types in Linn county. The more extensive types were sampled in triplicate, while in the case of the minor types, only one sample was drawn. All of the samples were taken with the utmost care that they should represent accurately the typical soil conditions and that variations due to local conditions or special treatments should be eliminated. The samplings were made in all cases 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.

Ananlyses 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 results given in the tables are the averages of duplicate determinations on all samples of each type analyzed. Where more than one sample of a type was taken, the results are the averages of four or six determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil to a depth of 6 2/3″.

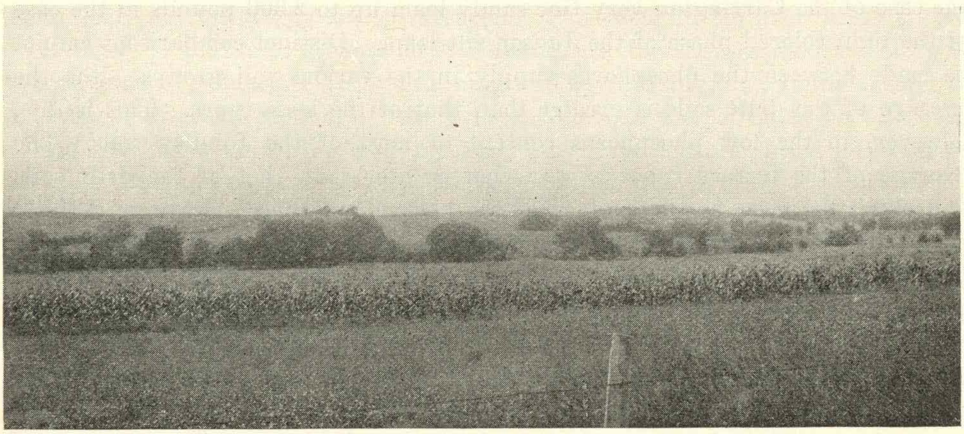


Fig. 2. Carrington silt loam, with Clinton silt loam in the background

TABLE IV. PLANT FOOD IN LINN COUNTY, IOWA, 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 SOILS					
83	Carrington silt loam	1,185	3,682	43,880	0	3,932
1	Carrington loam	876	1,830	24,220	0	3,574
84	Clyde silt loam	1,582	4,266	53,386	0	3,136
4	Carrington fine sandy loam	1,054	1,852	25,270	0	1,787
85	Clyde silty clay loam	1,872	9,420	132,480	0	Basic
34	Carrington very fine sandy loam	660	589	8,320	0	1,787
	LOESS SOILS					
80	Clinton silt loam	1,229	2,136	26,460	0	1,787
20	Tama silt loam	1,200	3,566	46,240	0	2,502
32	Lindley silt loam	1,226	3,450	46,400	0	357
36	Lindley fine sandy loam	731	885	12,952	0	1,286
65	Lindley loam	876	1,972	24,860	0	1,787
35	Lindley fine sand	795	618	7,753	0	1,429
37	Lindley very fine sandy loam	929	1,698	25,020	0	2,502
	TERRACE SOILS					
36	Buckner silt loam	1,268	3,183	39,370	0	5,772
88	Bremer silt loam	1,520	5,348	67,320	0	4,647
31	Judson silt loam	2,000	5,314	65,460	0	750
32	Judson silt loam (light colored phase	2,300	3,880	46,340	0	6,147
38	Buckner loam	1,138	2,357	26,200	0	2,144
45	Buckner fine sandy loam	1,130	1,954	24,060	0	4,682
40	Buckner sandy loam	1,010	1,072	15,740	0	2,502
43	Bremer silty clay loam	1,740	7,022	95,100	0	3,217
42	Calhoun silt loam	1,206	3,252	38,460	0	4,647
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,160	6,654	79,800	0	715
18	Cass loam	1,000	1,975	29,060	0	Basic
06	Cass silt loam	1,220	3,220	39,588	492	Basic
30	Cass fine sandy loam	1,185	1,644	20,820	0	1,072
33	Sarpy fine sand	835	1,786	11,100	0	2,502
21a	Muck	2,080	19,080	224,040	0	1,072

The phosphorus content is extremely variable, ranging from 660 pounds in he case of the Carrington very fine sandy loam up to 2,300 pounds in the case f the light colored phase of the Judson silt loam. Distinct comparisons cannot e made between the phosphorus supply in the various soil groups, altho the verage of the drift soils is greater than that of the loess types. This is due, owever, to the low phosphorus content of most of the Lindley soils. The verage of the terrace types is somewhat greater than that of the drift soils nd about the same as the average of the bottomland types. No very definite onclusions can be drawn from these comparisons, inasmuch as the variations in hosphorus content are greater among the various types within the different roups than they are between the various groups. In fact, there seems to be a nuch more distinct relation between the soil type and the phosphorus content. Thus, the silty clay loams and silt loams are much higher in this element than re the loams, sandy loams, fine sandy loams and very fine sandy loams. There re some exceptions, but in general these relations hold true. The low content of the Lindley soils is particularly noticeable, but this is the only case where there seems to be any relation between phosphorus supply and soil series, altho it may be noted that the Clyde soils are richer in phosphorus than the Carrington types, but this is really due to the fact that the Clyde soils are heavier in texture. The same comparison might be made of the Bremer and Buckner terrace series. While phosphorus is not actually lacking in any of the soil types in the county, in several instances it is very low and even where the total amount present is large, there is some doubt regarding the supply of the element in an available form.

There is no question but that phosphorus fertilizers will be needed in the near future on practically all of the soils in the county and it seems quite probable that they would prove of value now in many cases. These results point very clearly to the desirability of testing the use of phosphorus fertilizers. The field experiments which are now under way give indications of the value of various phosphate materials, but they have not been continued long enough to warrant definite conclusions. Farmers are urged to test phosphate materials on their own soils and thus determine whether phosphate fertilizers are of value and what particular form should be used.

The nitrogen content of the soils varies in much the same way as the phosphorus. The differences, however, are very much greater. The Carrington very fine sandy loam, which contains the smallest amount of this element, shows a content of only 589 pounds per acre, while the Clyde silty clay loam, which, except for the muck, is the best supplied with nitrogen, shows a content of 9,420 pounds per acre. As was noted in the case of phosphorus, there is very little relation between the nitrogen supply and the soil groups. The loess soils on the average are lower than the drift types. This again is due to the low nitrogen content of the Lindley soils. The average of the terrace types and of the bottomland types is not very different and varies but slightly from that of the drift soils. The relation between nitrogen supply and the soil type is more clearly shown. The silt loams and silty clay loams are very much higher in this element than are the loams or sandy loams.

In general, with the exception of two or three minor types, the soils of the county are not strikingly low in nitrogen. This element, however, must not be overlooked in planning systems of soil treatment, for the amount present will be continually reduced, both by cropping and by leaching, and if the supply is to be kept up, some method of returning nitrogen to the soil must be followed. Crops residues should always be returned and farm manure should be used in as large amounts as practicable, as these materials will provide for a considerable return of the nitrogen removed by crops. It is very often necessary to use some additional means of supplying nitrogen, as by the turning under of leguminous crops as green manures. These crops, when well inoculated, take a considerable part of their nitrogen from the atmosphere and thus have a distinct value because of the actual addition of nitrogen to the soil. They are also of value because of the fact that they supply organic matter. The use of legumes as green manures is particularly desirable in building up the nitrogen supply in the light, open, sandy soils in the county.

The organic carbon in the soil is a measure of the amount of organic matter resent, and serves also to indicate the nitrogen supply. Soils show a rather efinite relation between organic carbon and nitrogen. If there is a large nount of organic carbon present, there is usually a relatively large supply of itrogen, and vice versa. The amount of organic carbon in soils or the amount organic matter is indicated quite definitely by the color of the soils. Dark lored types are as a rule richer in organic matter and nitrogen, while the light lored soils are apt to be lacking in these constituents. The soils of Linn county e in general very well supplied with organic matter, as is indicated both by eir color and by the content of organic carbon. Again, as was noted in the se of nitrogen, there is a wide range in the amount of organic matter present. he soils of the Lindley series, with the exception of the silt loam, are somewhat wer in organic matter than the other types, as is true, also, of the phosphorus d nitrogen. There is no relation between the several groups of soils and the pply of organic matter, but the relations noted among the various soil types the case of nitrogen are borne out by the organic carbon results. The silty ay loams and silt loams are very much higher in organic matter than are the ams and sandy loams. While the supply of organic matter in many of the ils of the county is not low, applications of fertilizing materials supplying or-nic matter are necessary if this material is to be kept adequate. Indeed, it is ident from experiments and much farm experience that applications of farm anure are particularly valuable on Linn county soils. Even where the supply organic matter is considerable, applications of farm manure prove profitable. the case of the sandy types, the use of leguminous green manures in addition farm manure is very desirable in order to keep up the organic matter content, asmuch as it is usually impossible to supply sufficient farm manure for this urpose.

There is no inorganic carbon in any of the surface soils, with the exception the Cass silt loam, which shows a small amount, and the amount present in is soil is insufficient to prevent it from soon becoming acid. All but three of e types show a lime requirement when tested, and in none of those cases is ere a sufficient supply of lime; hence, the need for this material will soon be

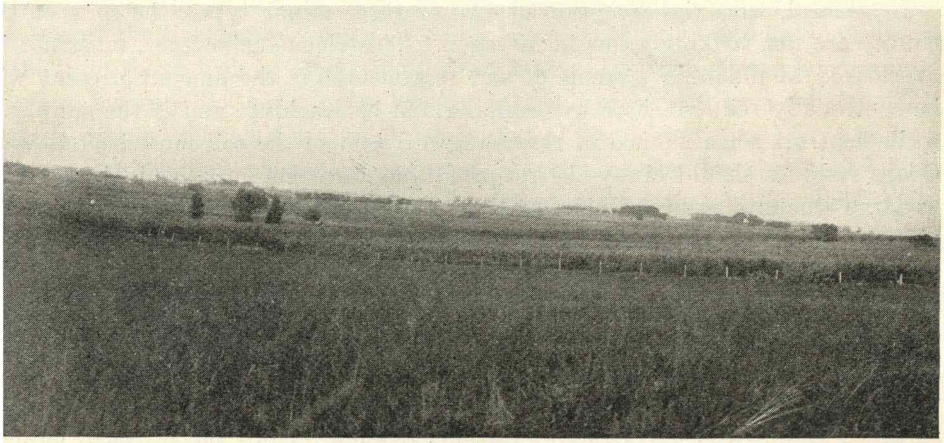


Fig. 3. Topography of Carrington silt loam northeast of Marion

evidenced. There is considerable variation in acidity, but the results given in the table should be considered indicative only of the needs of the various soil types. Soils vary widely in lime requirement, even within types, and it is quite necessary that tests be made in every case before lime is applied, in order to insure the application of the proper amount. It is apparent from these results that every soil in Linn county should be tested for acidity and the needed lime applied. Only in this way can the proper growth of crops, particularly of legumes, 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. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil. The plant food content of the lower layers has very little influence upon the fertility of the soil, unless the amount is large. The tables show that the subsurface soils and subsoils in Linn county are not rich in any constituent, and that there is in no case a large enough

TABLE V. PLANT FOOD IN LINN COUNTY, IOWA, 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 SOILS					
83	Carrington silt loam	1,640	5,170	53,060	0	6,434
1	Carrington loam	1,220	2,760	28,720	0	3,932
84	Clyde silt loam	2,227	4,408	51,387	0	4,289
4	Carrington fine sandy loam	1,740	2,248	25,320	0	4,048
85	Clyde silty clay loam	2,480	3,824	78,888	312	Basic
134	Carrington very fine sandy loam	800	376	5,092	0	3,574
	LOESS SOILS					
80	Clinton silt loam	1,667	2,206	22,520	0	2,460
120	Tama silt loam	2,120	5,144	66,240	0	5,004
32	Lindley silt loam	1,760	3,040	40,368	352	714
136	Lindley fine sandy loam	1,072	1,144	15,965	0	1,464
65	Lindley loam	1,320	3,112	25,280	0	1,430
135	Lindley fine sand	1,260	387	8,106	0	2,363
137	Lindley very fine sandy loam	1,320	2,036	29,400	0	3,574
	TERRACE SOILS					
36	Buckner silt loam	2,040	5,144	63,280	0	9,294
88	Bremer silt loam	2,920	9,030	113,400	0	7,864
131	Judson silt loam	3,840	6,868	87,240	0	2,144
132	Judson silt loam (light colored phase)	2,160	6,132	82,320	0	10,794
38	Buckner loam	1,620	3,372	.48,080	0	4,289
45	Buckner fine sandy loam	1,940	2,886	42,880	0	7,149
40	Buckner sandy loam	1,640	1,804	25,720	0	5,004
43	Bremer silty clay loam	1,840	7,704	110,480	0	3,574
42	Calhoun silt loam	1,720	2,716	30,600	0	6,434
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	2,080	11,196	153,680	0	714
18	Cass loam	2,080	3,968	43,456	344	Basic
106	Cass silt loam	1,200	980	11,720	0	Basic
130	Cass fine sandy loam	1,320	1,232	17,320	0	1,430
133	Sarpy fine sand	1,320	1,804	20,400	0	5,004
21a	Muck	3,680	38,424	430,120	0	1,500

TABLE VI. PLANT FOOD IN LINN COUNTY, IOWA, SOILS

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 SOILS					
83	Carrington silt loam	2,100	6,292	70,320	0	5,361
1	Carrington loam	1,290	1,416	14,910	0	4,288
84	Clyde silt loam	3,120	2,514	32,393	0	5,754
4	Carrington fine sandy loam	2,220	1,665	19,806	0	3,753
85	Clyde silty clay loam	3,360	1,986	24,552	228	Basic
134	Carrington very fine sandy loam	1,320	1,043	19,260	0	7,506
	LOESS SOILS					
80	Clinton silt loam	2,520	2,343	17,260	0	8,810
32	Lindley silt loam	2,040	3,528	24,840	0	7,506
136	Lindley fine sandy loam	1,752	956	12,349	0	2,573
65	Lindley loam	1,740	1,900	17,760	0	1,071
135	Lindley fine sand	1,100	423	11,037	0	3,574
137	Lindley very fine sandy loam	1,980	1,848	18,180	0	9,651
	TERRACE SOILS					
36	Buckner silt loam	2,250	2,197	61,320	0	10,188
88	Bremer silt loam	3,300	7,302	91,680	0	11,796
131	Judson silt loam	4,560	6,810	85,080	0	9,651
132	Judson silt loam (light colored phase)	4,140	2,410	21,360	0	3,216
38	Buckner loam	2,370	2,438	43,240	0	6,434
45	Buckner fine sandy loam	2,430	2,052	26,220	0	7,506
40	Buckner sandy loam	1,980	1,884	24,960	0	5,361
43	Bremer silty clay loam	2,520	3,696	58,632	588	Basic
42	Calhoun silt loam	3,120	1,224	14,940	0	15,015
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	2,400	9,000	139,440	0	1,071
18	Cass loam	1,800	664	10,680	0	Basic
106	Cass silt loam	1,320	218	6,240	0	Basic
130	Cass fine sandy loam	1,260	888	8,340	0	Basic
133	Sarpy fine sand	1,980	1,338	15,120	0	3,216
21a	Muck	4,380	7,608	121,152	348	Basic

supply to influence the fertility of the soil. These results, therefore, need not be considered in detail. It may merely be said that they serve to confirm the conclusions regarding the needs of the soils of the county which were reached from a consideration of the analyses of the surface soils. The phosphorus

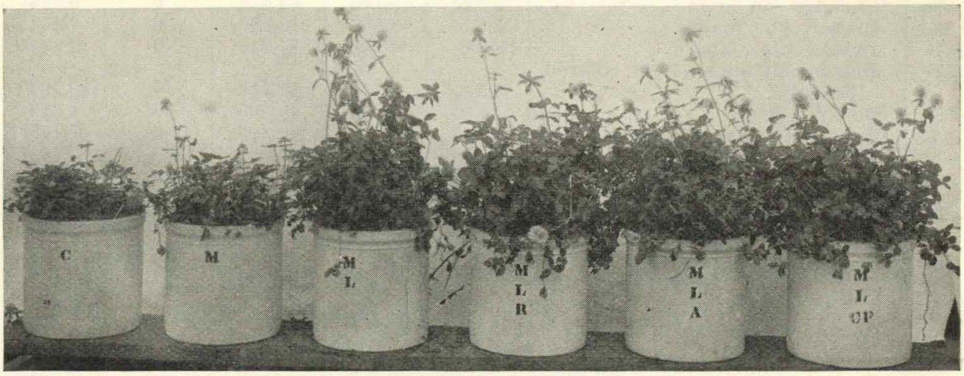


Fig. 4. Clover on Carrington silt loam, Linn county

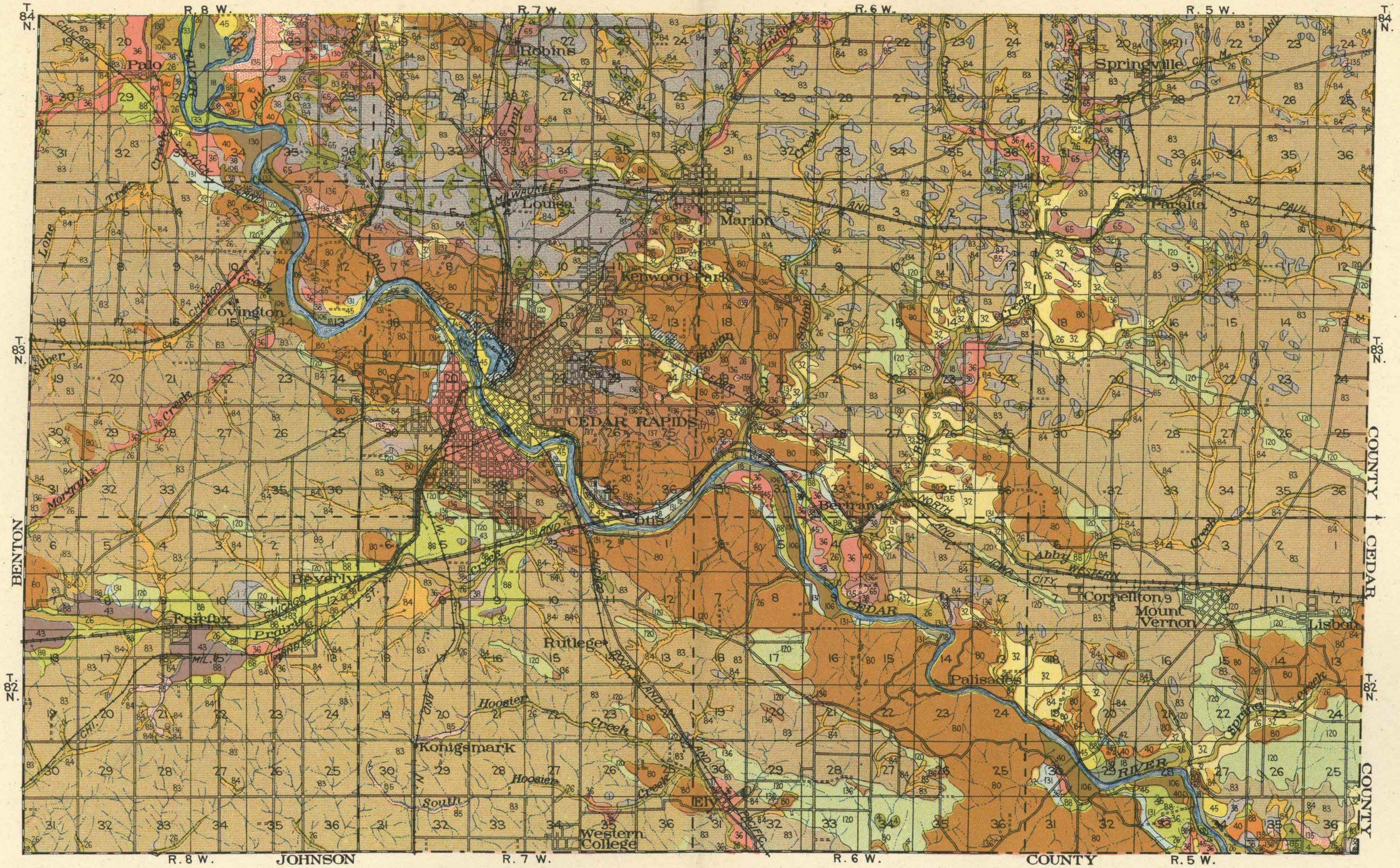
U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS
Milton Whitney, Chief. Curtis. F. Marbut, in charge Soil Survey.

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

SOIL MAP OF LINN COUNTY

LOWER HALF

Thomas D. Rice, Inspector Northern Division-Soils surveyed by F. B. Howe in charge and T. H. Benton of the Iowa Agricultural Experiment Station, M. Y. Longacre and A. H. Meyer of the U. S. Department of Agriculture.



LEGEND

Drift Soils

- 4 Carrington fine sandy loam
- 134 Carrington very fine sandy loam
- 1 Carrington loam
- 83 Carrington silt loam
- 84 Clyde silt loam
- 85 Clyde silty clay loam

Terrace Soils

- 42 Calhoun silt loam
- 88 Bremer silt loam
- 43 Bremer silty clay loam
- 40 Buckner sandy loam
- 45 Buckner fine sandy loam
- 38 Buckner loam
- 36 Buckner silt loam
- 131 Judson silt loam
- 132 Judson silt loam (light colored phase)

Swamp and Bottomland Soils

- 130 Cass fine sandy loam
- 18 Cass loam
- 106 Cass silt loam
- 133 Sarpy fine sand
- 21A Muck
- 26 Wabash silt loam

LEGEND

Loess Soils

- 135 Lindley fine sand
- 136 Lindley fine sandy loam
- 137 Lindley very fine sandy loam
- 65 Lindley loam
- 32 Lindley silt loam
- 80 Clinton silt loam
- 120 Tama silt loam

Scale: 1 Inch 2½ Miles

MIDLAND MAP AND ENGINEERING CO.
DES MOINES, IOWA

supply is not large and phosphorus fertilizers will be needed now or in the near future. The supply of organic matter and nitrogen is not extremely low, but these constituents will need to be supplied if the content is to be kept up. In some instances, there is particular need for these constituents at the present time. The reaction of some of the subsurface and subsoil samples is basic, that is, the samples were not acid, but in no case is there any considerable supply of lime present. The results in general confirm the conclusion that all the soils of the county should be tested for acidity.

GREENHOUSE EXPERIMENTS

Three greenhouse experiments were carried out on the soils of Linn county to gain some idea of the value of various fertilizing materials. In one experiment the Carrington silt loam was used, in the second, the Clyde silt loam, and in the third, the Clinton silt loam, all important types in the county. The results of these greenhouse experiments may be considered to indicate what may be expected in the field, but they do not necessarily prove what the results would be in field tests. Field experiments now under way in the county, which are considered briefly in the next section of this report, serve to indicate to what extent the field experiments have borne out these greenhouse results.

All three greenhouse tests were carried out according to the same plan, the treatments used being the same in all cases. Manure was added at the rate of

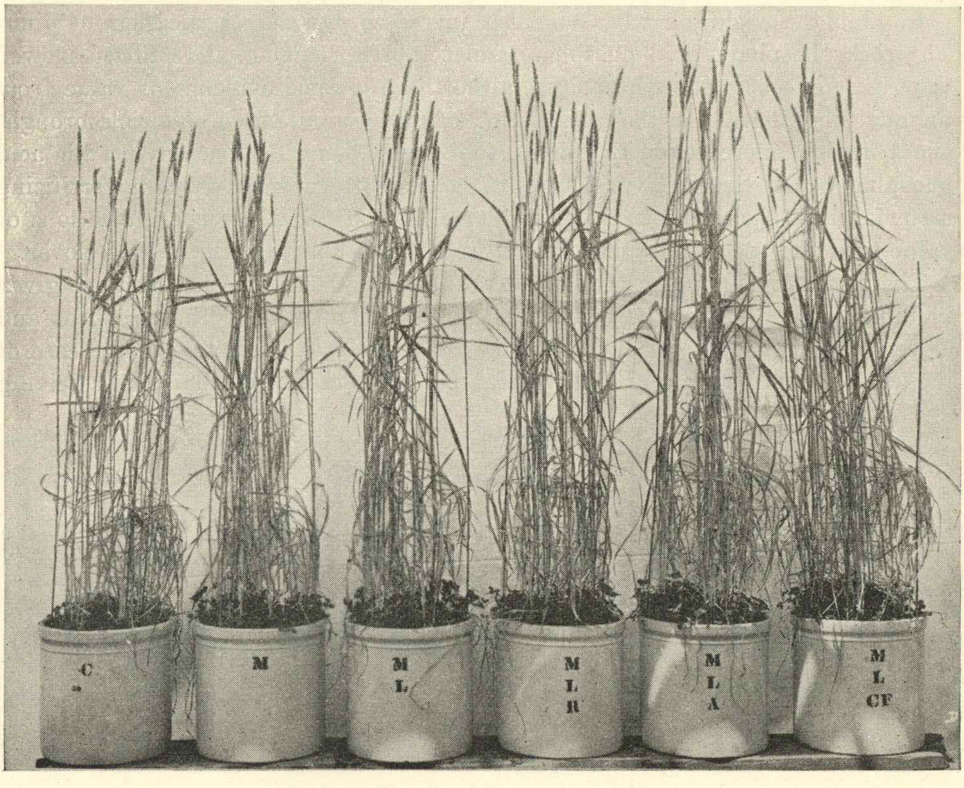


Fig. 5. Wheat on Carrington silt loam

TABLE VII. GREENHOUSE EXPERIMENT

Carrington silt loam—Linn county

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	16.74	10.5
2	Manure	18.29	16.0
3	Manure+Lime	22.00	28.0
4	Manure+Lime+Rock phosphate	22.50	32.0
5	Manure+Lime+Acid phosphate	23.53	34.5
6	Manure+Lime+Complete commercial fertilizer	21.13	33.0

3 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 on these plots in all 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 Carrington silt loam. The application of manure brought about a distinct increase in both crops, the effect being particularly noticeable in the case of the clover. When lime was supplied in addition to the manure, a still further increase was evidenced and in the case of the clover, this increase was very large, indicating the need of lime on this soil type when it is acid, if clover is to be grown successfully. It is interesting to note that the yield of wheat is also increased by the application of lime. The rock phosphate, acid phosphate and complete commercial fertilizer showed very little effect on the wheat crop, altho there is some evidence of value from the acid phosphate. In the case of clover, however, all three materials brought about distinct increases in the yields, the largest being evidenced from the acid phosphate. On this soil type, manure is evidently a very valuable fertilizing material, lime should be used when the soil is acid and there are indications of value from the use of phosphorus fertilizers, particularly in the case of clover.

The average results from the duplicate tests on the Clyde silt loam are given in table VIII. Again, the beneficial effect of manure on both the wheat and clover crops is shown, the influence being particularly noticeable in the case of the clover. Unfortunately, the results for both crops on the pots receiving

Fig. 6. Clover on Clyde silt loam

TABLE VIII. GREENHOUSE EXPERIMENT

Clyde silt loam—Linn county

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	13.94	39.0
2	Manure	15.73	62.0
3	Manure+Lime	....	...
4	Manure+Lime+Rock phosphate	15.82	68.0
5	Manure+Lime+Acid phosphate	16.00	71.0
6	Manure+Lime+Complete commercial fertilizer	16.49	69.0

manure and lime were very abnormal, for some unknown reason, and are not included here. The influence of the phosphates and of the complete commercial fertilizer is evidenced in the case of both crops, the acid phosphate showing up somewhat better on the clover, while the complete commercial fertilizer proved superior on the wheat. The effect of these materials is not as great on the clover as was the case in the experiment with the Carrington silt loam. This soil type is evidently benefited by the application of manure and there are indications that phosphorus fertilizers may be of value.

The results obtained on the Clinton silt loam are given in table IX. In this experiment the yield of clover was not obtained and the wheat yields only are given in the table. The effect of manure is very evident in these results, a considerable increase in the wheat crop being evidenced. Lime showed no effect, but it would hardly be expected that this material would exert any particular

Fig. 7. Wheat on Clyde silt loam

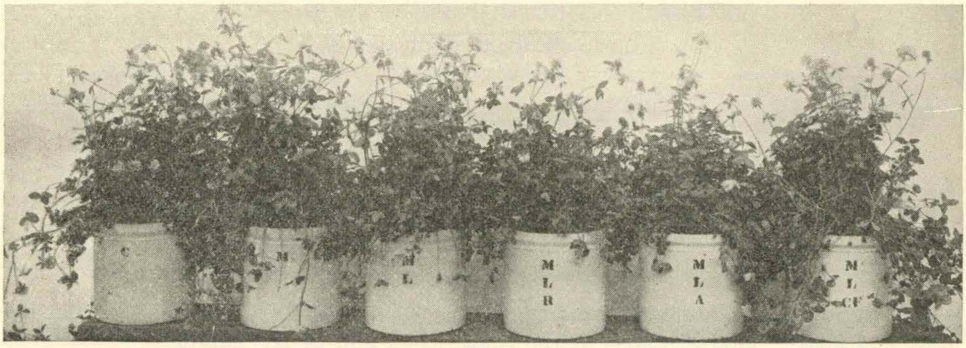


Fig. 8. Clover on Clinton silt loam

influence on the wheat, as this crop is not generally sensitive to acid soil conditions unless they become extreme. The rock phosphate, acid phosphate and complete commercial fertilizer gave some evidence of value, altho the increases were small. Rock phosphate showed up somewhat better than the other materials, with the complete fertilizer second. The least effect was evidenced in the case of the acid phosphate. It is apparent from these results that manure is the most important fertilizing material for use on the Clinton silt loam and that large increases in crop yields may be secured by its use. Lime should be applied when the soil is acid if the best growth of legumes is to be secured, and the beneficial effect of this material, while not shown in this experiment with wheat, would undoubtedly appear where legumes are grown. There are evidences of value from the use of a phosphate fertilizer, but the results are not definite enough to permit of recommendations for treatment.

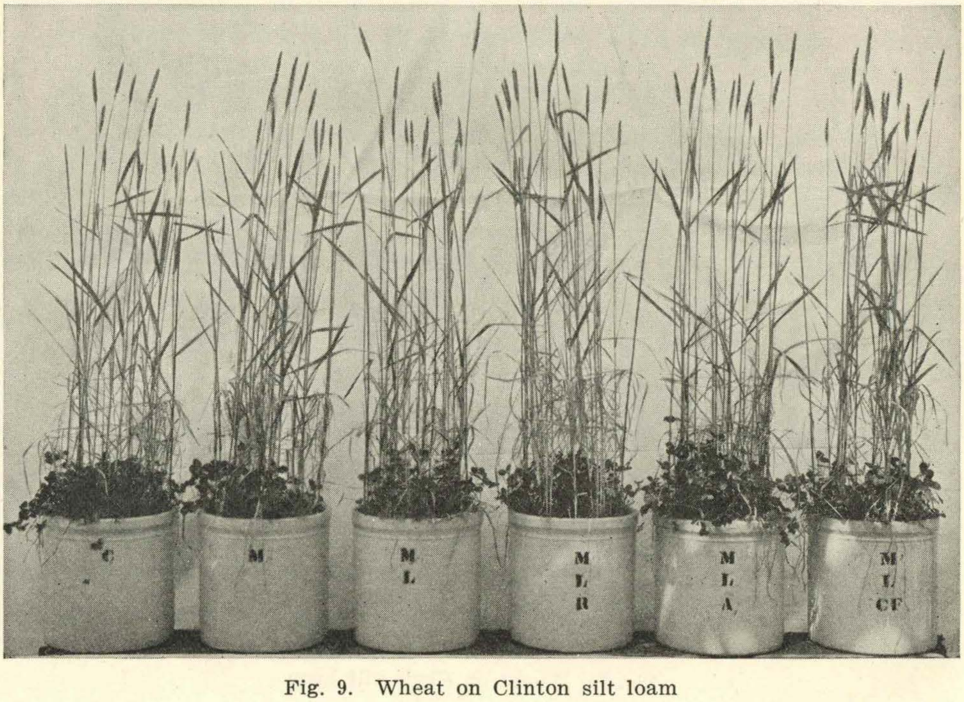


Fig. 9. Wheat on Clinton silt loam

TABLE IX. GREENHOUSE EXPERIMENT

Clinton silt loam—Linn county

Pot No.	Treatment	Wt. wheat grain in grams
1	Check	9.67
2	Manure	12.07
3	Manure+Lime	11.28
4	Manure+Lime+Rock phosphate	13.06
5	Manure+Lime+Acid phosphate	12.12
6	Manure+Lime+Complete commercial fertilizer	12.89

The greenhouse experiments as a whole indicate that the chief needs of the main soil types in the county are for manure, lime and phosphorus. Farm manure seems to give particularly large effects. In many cases where farm manure is not available in sufficient amounts, green manures would probably prove of value to supplement it. Lime proves profitable when used on legumes and phosphorus fertilizers give indications of being of considerable value. The particular phosphorus carrier which should be used must be determined by special tests, inasmuch as the results thus far secured in these greenhouse experiments and in the field experiments discussed in the next section of the report are not sufficiently complete to permit of definite recommendations.

FIELD EXPERIMENTS

Three field experiments have been started in Linn county, but one which was laid out at the same time as the others has had to be discontinued, owing to the transfer of ownership of the farm. These fields were all laid out in 1917 and only a few results have been secured to date.

On each of these fields one or more series of plots, 155 feet, 6 inches, x 28 feet, or 1/10 of an acre in size, were laid out to include tests, under the livestock and the grain systems of farming. In the former, manure is applied, while in the latter, crop residues are utilized as a source of organic matter. Other applications tested are limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. The manure is applied in all cases at the rate of 8 tons per acre once in a four year rotation. Limestone is added in a sufficient amount to neutralize the acidity of the soil and supply 2 tons additional. Rock phosphate is added at the rate of 2,000 pounds per acre once in a rotation, while acid phosphate is applied at the rate of 200 pounds per acre annually. A standard 2-8-2 complete commercial fertilizer has been used at the rate of 300 pounds per acre annually. On the grain system plots, the second crop of clover is plowed under, the corn stalks are cut with a disk and plowed under and the straw from the small grains is returned to the soil. The results on the crop residue plots on any of the fields are not included here, owing to the fact that they are somewhat irregular and the experiments have not been under way long enough for any effects from the residues to be shown. In all the experiments there are 13 plots, 3 of which are untreated, or check plots. Plots 1 to 7 inclusive are included in the livestock system, while plots 7 to 13 make up the grain system plots. In the tables, only the livestock system plots (1 to 7) are included.

TABLE X. FIELD EXPERIMENT

Clinton silt loam—Linn county—Waubeek field

Plot No.	Treatment	Clover tons per acre
1	Check	1.73
2	Manure	2.25
3	Manure+Lime	2.24
4	Manure+Lime+Rock phosphate	2.22
5	Manure+Lime+Acid phosphate	2.14
6	Manure+Lime+Complete commercial fertilizer	2.29
7	Check	1.68

THE WAUBEEK FIELD

The results obtained on the Waubeek field in 1918 are given in table X. This field is laid out on the Clinton silt loam and the crop grown in 1918 was clover. The results show very striking effects from the application of manure, a large increase in the yield of clover being secured. The other applications in addition to manure proved of little value. The results show very clearly that manure is a particularly valuable material for use on the Clinton silt loam in this county. The effect of the other fertilizing treatments might have been evidenced in later results, but unfortunately this farm was sold and it was impossible to continue the experiment.

THE SPRINGVILLE FIELD

The second experiment was carried out on the Carrington silt loam near Springville. The results obtained in Series I on this soil are given in table XI. The application of manure proved of considerable value, both on the clover in 1918 and on the corn in 1919, the increase being particularly noticeable in the case of corn. The application of rock phosphate, acid phosphate, and the complete commercial fertilizer all brought about distinct increases in the yields of clover, the effects being the same for all three materials. With corn, the acid phosphate gave an increase, but neither the rock phosphate nor the commercial fertilizer showed any value. Limestone did not bring about any increase in crop yields, either in the case of the clover or the corn. This is not surprising in the case of the latter crop, but some effect on the clover might have been expected. In general, when soil is acid, the proper application of lime should be made if the best crop growth is to be secured. Manure is evidently a very valuable fertilizing material for use on this soil and will give profitable returns.

TABLE XI. FIELD EXPERIMENT

Carrington silt loam—Linn county—Springville field

Series I

Plot No.	Treatment	Clover tons per acre 1918	Corn bu. per acre 1919
1	Check	2.25	58.6
2	Manure+Lime	2.40	63.7
3	Manure	2.47	64.8
4	Manure+Lime+Rock phosphate	2.70	60.8
5	Manure+Lime+Acid phosphate	2.70	67.1
6	Manure+Lime+Complete commercial fertilizer	2.70	64.5
7	Check	1.65	60.0

TABLE XII. FIELD EXPERIMENT

Clyde silt loam—Linn county—Alburnett field

Series I

Plot No.	Treatment	Bu. of corn per acre 1918
1	Check	47.7
2	Manure	60.4
3	Manure+Lime	62.4
4	Manure+Lime+Rock phosphate	62.5
5	Manure+Lime+Acid phosphate	60.4
6	Manure+Lime+Complete commercial fertilizer	55.4
7	Check	42.5

The use of phosphorus fertilizers may be of value in addition to manure and tests of the various materials are desirable, in order that definite conclusions may be drawn, particularly regarding the relative merits of acid phosphate and rock phosphate.

THE ALBURNETT FIELD

In table XII appear the results obtained in 1918 on Series I of the Alburnett field, which is located on the Clyde silt loam. Results were not secured in 1919, as the corn did not mature and was cut for silage. A very striking effect of manure is evidenced in the yields shown in the table. Lime gave a slight increase, but additions of the various phosphate fertilizers apparently had no value. These results are especially interesting because of the large increase in the yield of corn produced by the application of manure. This soil is well supplied with organic matter and it might be expected that manure would be of less value than on soils lower in this material. Probably the effect is very largely due to the improvement of physical conditions in the soil and to an increase in the production of available plant food. Evidently the application of manure to this soil is to be recommended.

In table XIII the results obtained on Series II of this same field are given. Clover was grown in 1918 on the series, and clover and timothy in 1919. The application of manure again showed value, both in the case of the clover and of the clover and timothy mixed. The application of lime with the manure brought about a distinct increase in the clover crop and some effect was still evidenced on the clover and timothy. The rock phosphate exerted little effect in 1918 and none at all in 1919. The acid phosphate, on the other hand, brought

TABLE XIII. FIELD EXPERIMENT

Clyde silt loam—Linn county—Alburnett field

Series II

Plot No.	Treatment	Clover and timothy tons per acre 1918	Clover and timothy tons per acre 1919
1	Check	1.92	3.20
2	Manure	1.98	3.76
3	Manure+Lime	2.24	3.88
4	Manure+Lime+Rock phosphate	2.28	3.32
5	Manure+Lime+Acid phosphate	2.54	4.04
6	Manure+Lime+Complete commercial fertilizer	2.34	3.32
7	Check	2.52	3.20

about distinct increases on both crops, the effect being particularly noticeable in the case of the clover. The commercial fertilizer showed some effect on the clover, but little influence the second year. The second check plot (7) was evidently somewhat abnormal in 1918 and the yield is rather high. In 1919, however, the abnormality had apparently been removed, as there is an exact agreement between the check plots. These results on the Clyde silt loam indicate that the application of manure is particularly valuable and will bring about distinct increases in crop yields. The use of lime when the soil is acid will prove of value, especially on the growth of clover. There are indications of value from the applications of a phosphorus fertilizer, in this instance acid phosphate showing up particularly well. The results are not sufficiently complete, however, to permit comparisons to be made among the various materials. Several years' results must be secured before a choice can be made between these various phosphorus carriers.

The field experiments, with the exception of the Waubeek fiield, are to be continued and it is hoped that the results secured during the next few years will permit of more definite conclusions regarding the needs of these soil types than are possible at the present time. The results given in this report should be considered indicative only of the value of certain soil treatments and they should not be interpreted too definitely nor too broadly.

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

The treatments recommended for the various soils of Linn county are based upon the laboratory and greenhouse experiments given earlier in this report, upon the indications from the field tests, and also upon practical experience. While the field experiments are not as complete as is necessary to permit of very definite conclusions, they do bear out the indications from the laboratory and greenhouse tests, and there is also much practical experience in support of the conclusions reached. The recommendations made are based therefore, not only upon the experimental work, but also upon the practical experience of farmers, and nothing is suggested which has not proved of definite value in the field.

LIMING

With the exception of three soil types, the Clyde silty clay loam, the Cass silt loam and the Cass loam, the soils of Linn county are distinctly acid at the surface. The more extensive types are all strongly acid in reaction. The lower soil layers of the various types show very little variation from the surface in lime requirement, with the exception of the subsoil of three types. In no case, even in the subsoil, however, is there any appreciable amount of inorganic carbon present; hence, there is evidently no considerable supply of carbonates. This indicates that lime will be needed on all the soils of the county at an early date, even if the reaction is not acid at the present time. All crops make their best growth on soils which are basic in reaction and in the case of legumes this is particularly true. In fact, with these latter crops, very frequently the acidity of the soil may be the controlling factor of growth and the application of lime may bring about very large and distinctly profitable increases in crop yields. Lime and other bases disappear from soils gradually and with continued cultivation there is a constant tendency toward an acid reaction. Lime should be applied according to the need of the soil and this must be determined at regular intervals by special tests. In other words, one neutralization of acid conditions will not be sufficient to keep the soil in the best reaction for an indefinite period of time. Tests should be made at a regular time in the rotation, as for example, preceding the clover in a four-year rotation. In this way, the best reaction for the growth of legumes may be assured and the effect of the application of lime will probably persist during the intervening period between succeeding clover crops.

It is evident that the soils of Linn county should all be tested for acidity and the amount of lime indicated as necessary should be applied. Farmers may test their own soils for acidity, but it will usually be much more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. It will thus be possible to determine the exact amount of lime needed, and excessive applications and, what is even more undesirable, the use of an insufficient amount, will be avoided. The results given in the tables earlier in this report should be considered merely as indications of the lime requirement on various soil types and applications of lime should not be based upon these figures. The reaction of the soil and the need for lime are extremely variable and even average results from several samples of the same type cannot be considered to show definitely the needs of all soils of the same type. Every soil should be tested before lime is applied in order that the proper amount may be used. It is always considered desirable to apply two tons of lime in addition to that needed to neutralize the acids present, especially if legumes are to be grown. The recommendations made by the Soils Section, therefore, include the use of sufficient lime to neutralize acidity, plus two tons. The acidity of the surface soil only is neutralized in following our recommendations, but inasmuch as lime gradually moves downward in the soil, there will be a constant neutralization of the acidity in the lower soil layers. This will be accompanied of course by a removal of lime from the surface soil, which is a further reason for the testing of soils at regular intervals to ascertain the need of lime.

The greenhouse and field experiments very largely confirm the laboratory data, indicating value from the application of lime to some of the main soil types. Furthermore, farm experience also supplies considerable confirmation of these results and shows that lime is a very profitable material for use on acid soils in the county. Without it, other treatments are generally less effective.

Further information regarding the use of lime may be found in Bulletin 151 and Circular 58 of the Iowa Agricultural Experiment Station.

MANURING

The organic matter content of the soils of Linn county is extremely variable and, while the amount present is considerable in some instances, in many of the types it is too small for the best fertility condition. The soils of the Lindley series, for instance, and some of the sandy types of other series, are really low in organic matter. These soils are, therefore, particularly in need of applications of manure or some other humus-forming material. The soils which are better supplied with organic matter at the present time, however, are also found to respond to applications of manure. In fact, manure often seems to be the most valuable fertilizing material which can be used. The greenhouse and field experiments, according to the results given earlier in this report, indicate very definitely the value of manure on several of the more important soil types. Thus, the value is shown in tests on the Carrington silt loam, the Clyde silt loam and the Clinton silt loam. In the case of the Clyde silt loam, the soil is well supplied with organic matter, but in spite of that fact, manure gives large increases in crop yields. There is no question but that many of the other types would respond equally well to applications of that material. Practical experience confirms these conclusions, inasmuch as the value of manure in increasing crop production is generally appreciated thruout the county. It seems evident, therefore, that manure should be recommended for use on the soils of the county in as large amounts as practicable, and such applications may be made with the assurance of profit. The amount of manure produced on the average farm is rarely greater than needed to apply 8 to 10 tons per acre once in the rotation; hence, there is little danger of making too large an application. It is probably true that in some instances, as for example on the very light colored, light textured soils, larger applications might be made with profit. It is not considered advisable, however, to apply more than 16 to 20 tons per acre and the returns secured from the larger amounts do not warrant their application.

Manure exerts a beneficial effect on crop production because of its physical, chemical and bacteriological effects on the soil. It opens up heavy clay soils and permits of better moisture and air conditions. It tightens up loose, sandy soil and permits of the greater retention of moisture and plant food in them. It adds considerable amounts of various plant food constituents to the soil, returning much of the nitrogen, phosphorus and potassium which has been removed in the crops used for feed. It may, therefore, exert a very important influence in lengthening the "life" of the soil. Manure contains enormous numbers of bacteria and when these organisms are introduced into the soil, they have a considerable effect on the production of available plant food. Increased crop production from the use of manure may be due to any one of these effects, but it is usually quite impossible to determine the cause of the beneficial influence. In the case of dark colored, rich soils, the value is supposed to be due very largely to the bacteria introduced. Small applications on low-lying, newly reclaimed lands high in organic matter, often prove very profitable, and the effect in such cases is undoubtedly largely bacterial.

The value of manure on soils may be materially reduced if the manure is not properly stored and applied. If it is exposed to the weather and the soluble portion is allowed to wash away, as much as 95 percent of its value may be lost and it will lose on the average three-fourths of its value. On the other hand, if it is properly stored, kept moist and compact and under cover, or if it is applied to the soil as produced, 75 percent of the plant food constituents of the crops used for feed may be returned to the soil. Thus the manure will lengthen considerably the time when the various plant food constituents in the soil will become lacking. There are various methods in use for the prevention of losses from manure, but no one method can be recommended for use under all conditions. It is highly desirable, however, that some method be chosen on every farm and some provision should be made for keeping the manure moist and compact and protected from weathering and leaching. It may sometimes be desirable and practicable to apply manure to the soil as produced and if this is done the losses are reduced to a minimum. The particular method of handling the manure must, however, be determined according to individual farm conditions.

The fertility of soils can not be maintained by the use of farm manure alone, even on the livestock farm where all the manure produced is carefully stored and applied to the soil. There is rarely enough manure produced to be distributed uniformly over the entire farm and permit of the addition of any considerable amount to every acre. On the grain farm, the production of manure is small, and some other means must be employed to keep up the supply of organic matter. Leguminous crops used as green manures constitute the most desirable substitute for farm manure on the grain farm, and on the livestock farm they may be used to supplement that material. Many legumes are available for growth under a wide variety of conditions and some one may be chosen which will be adapted for use in practically any rotation and under practically any climatic condition. Legumes have the ability when well inoculated, of utilizing the nitrogen of the atmosphere in their growth and when they are turned under they increase the amount of this constituent in the soil. They thus have a double effect in supplying not only organic matter but nitrogen also. In some instances, it may be desirable to use non-legumes as green manures, but when this is done there is no addition of nitrogen to the soil, the value of these materials lying wholly in the organic matter which they supply. The use of leguminous green manures on some of the poorer soil types in Linn county would undoubtedly prove profitable and in practically all cases these materials should be used in the rotation, if the fertility of the soil is to be maintained. It should be emphasized, however, that green manures are substitutes or supplements for farm manure and the latter material should always be applied as extensively as possible. While green manuring is often distinctly profitable, it will not give returns on soils in poor condition, and it should not be practiced carelessly, or the effects may be undesirable. Advice regarding the use of green manures in special cases will be given by the Soils Section upon requst.

On all soils, under all systems of farming, it is very important that crop residues, straw and stover, be completely returned. They constitute a very important part in keeping up the organic matter content of the soil. They are particularly valuable for this reason, but they also have an effect on the "life" of the soil because of the plant food elements which they contain. These materials are frequently burned or otherwise destroyed, actually causing a loss of constituents which are of considerable value to crop yields. On the livestock farm, the residues may of course be employed largely for feed or bedding and returned to the soil in the manure. In grain farming, they are sometimes applied directly to the soil, but often they are permitted to become partly decomposed before application. It is particularly important on the grain farm, where it is more difficult to keep up the organic matter supply, that the residues be fully utilized. In no case, however, should the crop residues be wasted, as they constitute one means of keeping up the fertility of the soil.

THE USE OF COMMERCIAL FERTILIZERS

The soils of Linn county are in general rather poorly supplied with phosphorus. In fact, in several cases the amount present is extremely small and it seems evident that the application of phosphate fertilizers will undoubtedly be necessary at an early date. It seems quite possible also that phosphate fertilizers might often prove of value at the present time. The greenhouse experiments and the field tests on three of the more extensive types in the county indicated the possibility of value from the use of phosphorus carriers. These experiments reported in the previous pages are merely indicative, however, of the general needs of the soils of the county. There is only one satisfactory method for determining the profits to be secured from applications of phosphorus and that is by actual tests in the field. The field experiments referred to above have not been under way for a sufficient length of time to permit of definite conclusions and it is therefore urged that farmers carry out tests on their own soils and thus solve the phosphorus problem for their own conditions. It is a simple matter to test the use of a phosphorus carrier on a small area and if it proves of value, applications may be made to a large area with the assurance of profit. Directions are given in Circular 51 of the Iowa Agricultural Experiment Station which will be of value to anyone intending to carry out such tests and advice will be given by the Soils Section in the case of special tests. There are two phosphorus carriers which may be employed, rock phosphate and acid phosphate. The former is considerably cheaper, but it is not as readily available and much larger applications of it must be made. Acid phosphate contains phosphorus in a readily available form, but as it is much more expensive than rock, it is desirable to determine which of these materials will give the best results, not only in largest crop yields, but also in largest returns for the money invested in the fertilizer. Farmers may use both of these materials in simple tests on their own soils and determine which is the more profitable for use under their particular conditions. Applications of the material showing the greater value may then be made to large areas and returns on the money invested will be assured.

It is essential that the nitrogen supply in soils be kept up and some means must be employed for this purpose. Linn county soils are not in general strikingly deficient in nitrogen, but in many cases the amount is so low that nitrogen may soon become the controlling factor of growth. It is evident, therefore, that this element must be applied to many of the soils. The best method of supplying nitrogen is by the use of the leguminous crops as green manures. When legumes are well inoculated and are turned under in the soil, the nitrogen supply is increased to a considerable extent. The use of these crops in this way renders unnecessary the application of commercial nitrogenous fertilizers and not only is the nitrogen supply maintained, but there is also an addition of organic matter which is of much value. The addition of nitrogen in the form of leguminous crops might be of considerable value on some of the soils of Linn county at the present time and they will undoubtedly be needed for permanent fertility. Commercial nitrogen carriers may possibly be used to advantage as top dressings for the stimulation of the early growth of some crops, but their application for general farm crops cannot be recommended at the present time. If any nitrogenous material proves profitable under any particular soil conditions, however, that material may be used without fear of injury to the soil.

The potassium content of the soils of the state has been found to be so large that it seems unlikely that potassium fertilizers should be needed. Linn county soils are presumably well supplied with potassium and if they are kept in the best physical condition for bacterial action, there should be a rapid production of sufficient available potassium. The use of potassium fertilizers is not recommended, therefore, but if tests on small areas prove any particular potassium carrier to be of value, that material may well be employed on a large area. There is no objection to the use of potassium fertilizers. It is merely a question of profit, or in other words, whether the increased crop growth will pay for the application.

Complete commercial fertilizers contain nitrogen, phosphorus, and potassium. If sufficient nitrogen is supplied to the soil by the use of inoculated legumes and if the physical condition of the soil is kept at the best for bacterial action, there should be no need of supplying nitrogen and potassium, and it seems doubtful, therefore, if complete fertilizers would prove as profitable on these soils as phosphorus carriers. In the field tests, a complete fertilizer is tested along with the rock phosphate and acid phosphate, but thus far there is no definite evidence from the results. It may be possible later to determine whether such materials can be used with profit, but for the present they cannot be recommended without special tests. Farmers may test these materials at the same time that they are testing rock phosphate and acid phosphate and thus determine the relative value of the various materials. In fact, it is urged that if a complete fertilizer is tested, a comparison be made of its value with that of a phosphorus carrier. This is necessary in order to determine whether phosphorus alone will not prove more profitable. There is no objection to the use of complete commercial fertilizers, provided they yield economic returns. They do not injure the soil and the whole question is one of profit secured from their use, or rather, the relative profit compared with that from the use of a phosphorus carrier.

DRAINAGE

The soils of Linn county are not generally in need of drainage, but there are some areas where the drainage is poor and tiling would prove of much value. The Clyde silt loam and, particularly, the Clyde silty clay loam, are in need of drainage, and there are some other upland types, as for example the Carrington loam and the Carrington silt loam, in which there are areas which would be improved by tiling. The Bremer silt loam, Bremer silty clay loam and the Calhoun silt loam are all somewhat in need of drainage and, among the bottomland types, the Wabash silt loam and muck are poorly drained. In all these cases the use of tile would be extremely profitable. Indeed, in some instances satisfactory crop yields could not be secured without drainage. Where the moisture content is excessive, crop production is certain to be low and no other method of treatment will take the place of drainage. Even tho the cost is considerable, it is a paying proposition, and tile should be installed if crop yields are to be satisfactory.

THE ROTATION OF CROPS

No special experiments dealing with crop rotations have been carried out in Linn county, but there are various rotations in use thruout the state which may be suggested as satisfactory. No one rotation can be recommended for all conditions, but there are many modifications of those given below which may be employed and, provided certain facts are kept in mind, almost any rotation would be satisfactory. It is a matter of common knowledge that some rotation should be followed on all soils and that the continuous growing of one crop is much less profitable than a rotation. Even if a particular crop is the money crop, that crop should not be grown continuously, but a rotation containing it should be followed. The actual income over a period of years will be greater where the rotation is followed and, furthermore, the rotation is necessary if the soil is to be kept permanently fertile. Any rotation which is chosen should contain a legume, because of the value of such crops in keeping up the organic matter and nitrogen content.

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, so 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 or non-occurrence of this injurious action.

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

Light, open soils which absorb water readily are not apt to be subject to erosion, while heavy soils such as loams, silt loams and clays, may suffer much from heavy or long-continued rains. Loess soils are 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 subject to erosion, while land in sod is not affected. The character of the cropping of the soil may, therefore, determine the occurrence of the injurious action. 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 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. Such materials increase the absorbing power of the soil and 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 be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient.

In Linn county, erosion occurs to a large extent in the Clinton silt loam and to a less extent in the Tama silt loam, the Lindley silt loam, the Lindley loam and the other types belonging to the Lindley series.

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

EROSION DUE TO DEAD FURROWS

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

"Plowing In." It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas where the soil is deep, this "plowing in" process may be very effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may

ot 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 ıd there is less danger of washing out. The process consists in driving in sev- ·al stakes across the gully and up the entire hillside at intervals of from 15 to) yards, according to the slope. The stakes in each series should be placed ıree to four inches apart and the tops of the stakes should extend well above the ırrounding land. It is then usually advisable to weave some brush about the ;akes allowing the tops of the brush to point up-stream. Additional brush may lso be placed above the stakes with the tops pointing up-stream, permitting the ater to filter thru, but holding the fine soil.

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

SMALL GULLIES

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

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

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

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

The Christopher or Dickey Dam. This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow, or a "T" being inserted in the tile just above the dam. This "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used 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 entirely satisfactory, especially when tile openings have been provided in the dam at various heights. The efficiency of the stone dam depends 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, in the same way as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The Woven Wire Dam. The use of woven wire, especially in connection with brush or rubbish, has sometimes 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 usually other methods are preferable.

Sod Strips. The use of narrow strips of sod along natural surface drainage-ways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation is relatively small, as the strips are usually only a rod or two in width. Blue-grass is the best crop 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 might be employed to advantage in many other cases.

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

Drainage. The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to the depth of the tile increases the 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 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 prevent it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

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

Straightening and Tiling. The straightening of the larger streams in bottom-land 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 bottom-land and often proves very efficient.

Trees. Erosion is sometimes controlled by rows of such trees as willows, which extend up the drainage channels. While the method has some good features, it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with.

Furthermore the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches, the presence of trees may be effective in controlling erosion, but a row of trees across cultivated land, or even extending into it, cannot be recommended.

HILLSIDE EROSION

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

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

Growing of Crops. The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years, is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also desirable for use in such locations. The root system of such crops as these holds the soil together and reduces the washing action of rainfall 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 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 to small grain, and also on fall plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first, as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Deep Plowing. Deep plowing increases the absorptive power of the soil and decreases erosion. It is especially advantageous if it is done in the fall, as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation, as too much subsoil may be mixed with the surface soil and its productive power 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 less subject to erosion.

INDIVIDUAL SOIL TYPES IN LINN COUNTY*

There are twenty-seven individual soil types in Linn county and an area of muck, making a total of twenty-eight separate soil areas. They are divided into four large groups according to their origin and these groups are known as drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are six drift soils in the county, belonging in the Carrington and Clyde series, and as a whole they cover almost three-fourths of the total area of the county.

CARRINGTON SILT LOAM (83)

The Carrington silt loam is the largest individual soil type, covering 225,664 acres or 49.7 percent of the county's area. This type is of extensive occurrence on the uplands in the central portion, between the Cedar and Wapsipinicon rivers. It is also found extensively south and west of the Cedar river in Clinton, Fairfax, and College townships. The largest individual areas occur in the latter location, where the soil is also more typical.

The surface soil of the Carrington silt loam to a depth of 8 to 12 inches is a dark grayish-brown or nearly black, friable, silt loam to fine loam. The subsurface soil is a dark brown, heavy silt loam, passing abruptly at about 32 inches into a yellowish-brown or light brown, gritty clay loam or silty clay loam. The lower subsoil frequently contains much coarse material, glacial pebbles and boulders. Near Walker and southward toward Center Point, huge drift boulders are common. In the northern part of the county, in Maine, Marion, Brown and Boulder townships, the soil is somewhat different from the typical silt loam, containing a rather high percentage of sand, especially in the subsoil. North of Alburnett and in other sections near that place, there is also a variation from the typical silt loam, the subsoil becoming a dark gray or yellowish-gray silty clay mottled with brown. This variation of the type is apt to be in need of drainage. A third variation from the typical soil is found near Mt. Vernon and Lisbon. In this area, the soil is very silty, resembling the Tama silt loam. It consists of a dark brown or nearly black, friable, rather heavy silt loam, to a depth of 15 inches. This is underlaid by a dark brown, heavy silt loam to silty clay loam. Some glacial boulders are found on the surface, but they are not abundant.

In topography, the Carrington silt loam is undulating to gently rolling, with a few almost flat or level areas. With the exception of the area near Alburnett mentioned above, the drainage of the type is usually satisfactory, but in some cases the installation of tile is desirable.

The Carrington silt loam is practically all under cultivation, corn being the chief crop grown. Average yields of 40 to 50 bushels per acre are secured and in many instances the yields are very much higher. Oats are second to corn in acreage and in favorable seasons the yields of this crop are large. Clover and timothy are grown for hay and prove very satisfactory. Alfalfa is also produced on small areas.

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

This soil is rather productive on the average, but with proper treatment, crop yields may be considerably increased. The application of manure is of special value, as has been shown in the greenhouse and field tests. This material should evidently be applied to the soil in as large amounts as practicable and profitable crop increases will be secured. The soil is not particularly high in organic matter and nitrogen and if farm manure is not available in sufficient amounts for application, leguminous green manures should be employed. The soil is acid and should receive applications of lime if satisfactory crop growth, particularly of legumes, is to be secured. The phosphorus content is low and applications of phoshorus fertilizers will probably prove of value. The greenhouse and field tests give indications of profit from the use of rock phosphate or acid phosphate. Definite choice between these two materials cannot yet be made and it is urged that farmers test the two materials on their own soils to determine for their particular conditions which fertilizer should be employed. In some areas, drainage is necessary; crop residues should, of course, be completely returned to the soil, and a suitable rotation of crops should be practiced. With these treatments, crop production on this soil may be made and kept entirely satisfactory.

CARRINGTON LOAM (1)

The Carrington loam is the county's second largest soil type, covering 45,504 acres or 10 percent of the total area. It is usually found associated with Carrington silt loam, occurring on low mounds or ridges in the silt loam. The largest areas of this type are found in the northern part, but it occurs also in rather extensive areas thruout the central portion of the county between the Cedar and the Wapsipinicon rivers and also northwest of the Wapsipinicon. It is not found in the southeastern part of the county.

The surface soil of this type is a dark brown or nearly grayish-brown loam or fine loam, extending to a depth of 10 to 12 inches. There is a relatively small amount of sand present, which is medium or fine in texture. The subsoil is somewhat heavier and more compact, and at 20 inches becomes a brown, light brown or yellowish-brown, fine loam or fine sandy loam. At 30 to 36 inches, the subsoil is a yellowish-brown or light brown sandy loam to yellow fine sand. The subsoil contains considerable coarse sand and many glacial pebbles. Boulders are frequently found on the surface. With this type there are included small areas of a darker brown loam, underlaid by a yellowish-brown gritty clay loam or silty clay loam. Small scattered areas of a more sandy loam, occurring on rounded ridges within the typical soil, are included because of their small extent. Small areas are frequently found where the soil is a fine loam, with a fine sandy loam or coarse silt subsoil. These areas are also included in the typical soil because of their small extent.

In topography the Carrington loam is generally rolling to sligthly undulating. The slopes of the individual mound and ridge areas are usually gentle. The drainage of the type is generally good, but occasionally in the lower areas, tiling would prove of value.

Practically all of the soil is under cultivation, general farm crops being grown. Corn is the most important crop and yields 40 bushels per acre on the average. Oats average 30 to 35 bushels per acre and clover and timothy, the chief hay rop, yield 1 to 1½ tons per acre. Under favorable conditions, the yields of all nese crops are considerably increased.

Crop production on the Carrington loam is fairly satisfactory, but proper soil reatment will bring about large increases in crop yields. Applications of farm anure have proved of much value. This material should be applied to the oil in as large amounts as practicable. Leguminous green manures may also e used with profit in many cases. The soil is acid and lime should be used n the amount shown by special tests to be necessary. Phosphorus fertilizers ill undoubtedly be needed soon and may often prove profitable at the present ime. Tests of rock phosphate and acid phosphate on individual farms are ery desirable. With these treatments, the Carrington loam may be made much ore highly productive than at present.

CLYDE SILT LOAM (84)

The Clyde silt loam is the third largest drift soil and the fourth largest indi-idual soil type in the county. It covers 31,636 acres or 7 percent of the total rea. It is found chiefly in the northwestern section between the Cedar and Vapsipinicon rivers, altho small areas are also present south and west of the Cedar river in the southwestern part. In practically all cases, it is found on mall draws extending for some distances up the slopes. It is also found, how-ver, on rather extensive, level to flat areas in the midst of the typical Carring-on silt loam of the upland.

The surface soil of the Clyde silt loam to a depth of 6 inches consists of a lack, heavy, silt loam. It is underlaid by a black, heavy, silty clay loam or ilty clay. At 24 inches, the material becomes a yellowish-gray, plastic, silty, lay, somewhat mottled with brown and light brown. Pebbles and gritty mat-rial occur in the subsoil and occasionally pockets or layers of sand are found, specially in the lower subsoil.

A variation of the Clyde silt loam occurs in several areas and this variation onsists of a grayish-black or black heavy silt loam to a depth of 15 inches. From 15 to 22 inches, the soil is a dark gray, heavy, silt loam or silty clay loam, vith faint mottlings of brown or grayish-brown. At 22 to 30 inches the subsoil ecomes a compact, impervious, gray or grayish-yellow, heavy, silty clay, with nottlings of brown and reddish-brown, and below this, the subsoil is less com-pact, grading into a yellow, silty clay loam with reddish-brown and dark brown nottlings. Pebbles and boulders are present thruout the subsoil. The drain-age of this variation from the typical soil is particularly poor and crop produc-ion is entirely dependent upon the use of tile.

In topography, this soil is level to flat. The larger areas are flat, while the maller ones are found in depressions. In all cases, however, the soil is lower han the surrounding land and the drainage is poor. Tiling has proved of con-iderable value in making this soil more productive.

The larger areas of the Clyde silt loam are generally cultivated, but much of he type is still used for the production of hay and for pasture. Corn is the nost important crop grown on cultivated areas and, when the land is well drained, good yields are secured. Small grains also prove of value on drained areas. Hay and pasture grasses grow luxuriantly.

This soil is highly productive when properly drained. It is acid, however, and lime should be used to grow legumes satisfactorily. Small applications of farm manure would undoubtedly prove of value, especially on newly drained areas. The phosphorus supply is not particularly high and phosphorus fertilizers will undoubtedly be needed in the near future. There were evidences of value from the use of these materials in the greenhouse and field experiments, and it is suggested that farmers test the use of acid and rock phosphate on this type and determine which is the more profitable material for use under their particular conditions.

CARRINGTON FINE SANDY LOAM (4)

This is a minor soil type in the county, covering 11,776 acres or 2.6 percent of the total area. It is found chiefly in association with the Carrington loam, but some areas are also found associated with the Tama silt loam. There are several large areas of this soil, chiefly in the northeastern part of the county. Many smaller areas are found in other parts of the county. It usually occurs on ridges and slopes, generally adjacent to the streams and frequently separating the Carrington loam from the terrace and bottomlands.

The surface soil of the Carrington fine sandy loam is a brown or dark grayish-brown, loose, friable, fine sandy loam, 10 to 15 inches in depth. There is little change in the soil to a depth of 24 inches, at which point it becomes a grayish-yellow or brown fine sandy loam, containing somewhat more silt and clay than the surface soil. Below this, the subsoil is a yellowish-brown to light brown sandy loam or loamy fine sand. Small areas of fine sand are frequently included within this type, owing to their small extent. In topography, this soil is undulating to rolling and is usually well drained. In fact, in many cases the drainage is excessive.

A large part of this type is forested with a growth of oak and hickory and an undergrowth of blackberry, sumac and other shrubs. In the cultivated portion, general farm crops are grown, but it is generally believed that the soil is best suited to pasture or hay, owing to its tendency to drift. The rougher areas along the streams are chiefly used in this way. In the cultivated areas, the soil is particularly in need of heavy applications of farm manure or the use of leguminous green manure crops. It is acid, and lime should be applied. It is low in phosphorus, and applications of phosphorus fertilizers would probably prove of value.

CLYDE SILTY CLAY LOAM (85)

This is a very minor type, covering only 1,024 acres or 0.2 percent of the county's total area. It occurs in small areas associated with the Clyde silt loam and in most cases is found in depressed areas at the head of or along drainage ways.

The surface soil of this type is a black, friable, silty clay loam, to a depth of 10 inches. It is underlaid by a grayish-black, compact, silty clay, somewhat mottled with brown. At 24 inches it grades into a gray or dark gray, plastic silty clay, mottled with brown or dark brown. In topography, it is depressed and it is naturally poorly drained.

Only a few areas of the type are farmed, corn being the chief crop grown. Bluegrass grows well and the soil is largely used for pasture. If this type is to be cultivated, its first need is for adequate drainage and when this is accomplished by the proper use of tile, satisfactory crop yields may be secured. Small applications of farm manure might prove of value on newly drained land. Lime will be needed in some instances and phosphorus fertilizers must eventually be applied.

CARRINGTON VERY FINE SANDY LOAM (134)

This soil type is of very small occurrence, occupying 576 acres or 0.1 percent of the county's area. It is found in many small areas closely associated with the Carrington loam. Southeast of Troy Mills, it covers part of a conspicuous ridge and it occurs in a similar position southeast of Robins.

The surface soil to a depth of 22 inches is a brown or dark brown, very fine sandy loam or sandy loam. At this point it grades into a light brown or yellowish-brown fine sand or loamy fine sand.

This type is largely under cultivation, but it is subject to considerable erosion, especially on the steeper slopes. Owing to its occurrence, which is mainly on slopes, it is particularly in need of protection from erosion. The addition of organic matter would be of value, especially the use of farm manure or leguminous green manures. It is acid and in need of lime. It is very low in phosphorus and the use of phosphorus fertilizers would probably prove profitable where cultivated crops are grown.

LOESS SOILS

There are seven loess types in the county, belonging in the Clinton, Tama and Lindley Series. The loess soils as a whole cover a considerable area, amounting to 82,176 acres or 18.1 of the total area.

CLINTON SILT LOAM (80)

The Clinton silt loam is the most extensive loess soil and is the county's third largest individual soil type. It covers 40,128 acres, or 8.8 percent of the total area of the county. It occurs in extensive areas along the Cedar river and also along the Wapsipinicon river and Buffalo creek. It is found chiefly on the high ridges adjacent to the streams. The surface soil is a light brownish-gray or yellowish-brown, friable silt loam, extending to a depth of about 8 inches. Below this point it is light brown or dark yellowish-brown, heavy silt loam or silty clay loam. At 18 inches it becomes a light brown or yellowish-brown silty clay loam or silty clay. In some areas north of Waubeek and southeast of Cedar Rapids, there is a variation from the typical silt loam, where the soil is a light, brownish-gray silt loam, 8 inches in depth, underlaid by a light brown or yellowish-brown, friable, silty clay loam. This phase is lighter in color than the typical Clinton. It possesses a heavier forest growth and in many cases is subject to more extensive erosion.

The typical Clinton silt loam is rolling to rough in topography. The type is generally subject to extensive washing and in many cases the fertility has been reduced or crop production prevented by the injurious erosion.

The type was originally forested mainly with white, red, scarlet and bur oak. A considerable area is still timbered and, besides the trees mentioned, hickory and hazelbrush are common. The forested areas furnish excellent pasturage. Corn is the chief crop grown on the cultivated portion of the type and oats is second in value. Some trucking is done on this soil, mainly near Cedar Rapids.

The chief need of this soil is for protection from erosion, which seriously interferes with satisfactory crop production. Some one of the methods mentioned in the section of this report dealing with erosion, should be chosen, to prevent further washing or to reclaim badly eroded areas. The soil is also very much in need of organic matter, and applications of farm manure should be made in as large amounts as practicable. Leguminous green manures may also be employed profitably in many cases. The soil is acid and in need of liming. It is low in phosphorus, and applications of phosphorus fertilizers would probably prove of value at the present time and undoubtedly will be needed in the future.

TAMA SILT LOAM (120)

The Tama silt loam is the second largest loess soil, occupying, however, a much smaller area than the Clinton. It covers 15,552 acres or 3.4 percent of the county's total area. It is found in many scattered areas, most of them relatively small. The largest developments of the type are found in the southeastern part and in the northeastern section. It occurs usually on ridges and is associated with the soils developed along the rivers. Some areas are found, however, on so-called ''pahas'' in the Carrington silt loam.

The surface soil is a dark brown, friable silt loam to a depth of 12 inches. At that point it becomes a dark brown or brown, heavy, silt loam or clay loam, grading at 20 inches into a light brown or yellowish-brown, friable, silty clay loam. In topography the soil is gently rolling. Drainage is usually adequate.

Practically all of this type is cultivated or used as pasture. Corn is the chief crop grown and yields are very satisfactory. Oats and wheat are produced to some extent and clover and timothy are the leading hay crops. Alfalfa is grown on a small acreage. This soil is highly productive at the present time, but it will respond to proper treatments and is in need of certain fertilizing materials if it is to be kept permanently fertile. It is acid, and lime should be used for the best growth of legumes. Farm manure will prove profitable and should be used in as large amounts as practicable. The phosphorus supply is low and applications of phosphorus fertilizers may be of value. In any case, however, they will certainly be needed in the future.

LINDLEY SILT LOAM (32)

The Lindley silt loam is the third largest loess soil, covering 10,176 acres or 2.2 percent of the county's area. It occurs only on small areas or strips of upland bordering the more important streams. The largest areas are found in the southwest part of the county, along the Cedar river and Big creek. Other areas of considerable extent occur near Toddville and along the Wapsipinicon, southeast of Troy Mills.

[T]he surface soil is a light, grayish-brown or gray, rather compact, silt loam, [ext]ending to a depth of 8 to 10 inches. Below that point it becomes a light [bro]wn or light yellowish-brown, compact silty clay loam. At 24 inches the sub[soi]l is somewhat lighter in color and heavier in texture, becoming a light [bro]wn to yellowish-brown, silty clay loam or silty clay. At 30 inches the sub[soi]l is a gritty, yellowish-brown, clay loam, and at 36 inches a light, yellowish-[br]own sandy loam. At lower depths, a layer of sand is frequently encountered. [Th]is is particularly true of the areas adjacent to streams. In many places the [sub]soil is compact to a depth of three feet. The soil is rolling to rough in topo[gr]aphy and is subject to considerable washing. The drainage is good. A large [pa]rt of this type is still forested, but considerable areas have been cleared and [br]ought under cultivation. The crop yields are somewhat lower than on the other [up]land types. It needs particularly protection from erosion and the applica[tio]n of farm manure in liberal amounts, and would probably be benefited by the [us]e of leguminous green manures and by the application of phosphorus fertil[ize]rs. The incorporation of organic matter in the soil is particularly necessary [to] increase crop production.

LINDLEY FINE SANDY LOAM (136)

This type is slightly smaller in extent than the Lindley silt loam, covering 9,344 [ac]res or 2.1 percent of the county's area. It occurs in numerous small areas along [th]e rivers, particularly the Cedar and the Wapsipinicon, the largest areas being [fo]und in the northeast part along the latter river. There is one area, however, [ju]st northwest of Cedar Rapids which is rather extensive.

The surface soil of this type is a grayish-brown fine sandy loam or fine loam [ex]tending to a depth of 18 inches. This is underlaid by a brown or light [gr]ayish-brown fine sandy loam or loamy fine sand. Below 30 inches the subsoil [be]comes a light brownish-gray loamy fine sand. In some areas, especially [in] depressions, the subsoil is a gritty or sandy dark brown or yellowish-brown [sil]ty clay loam. Pebbles and gravel are found scattered thruout the surface [so]il and subsoil.

In topography this type is usually gently rolling to rough and the drainage [is] good. Occasionally drainage is excessive and in some of the depressed areas [ha]ving heavy subsoils, tiling would be of value.

A large part of the type is under cultivation, the rougher areas being left in [ti]mber and in pasture. The timber growth consists mainly of white oak and [hi]ckory, with an undergrowth of sumac and other shrubs. On the cultivated [ar]eas, small grain and corn are the chief crops grown, but the yields are not [ve]ry satisfactory.

This soil, like the Lindley silt loam, is particularly in need of liberal applica[ti]on of farm manure. Leguminous green manures would also prove of value in [m]any cases, supplementing the farm manure. The soil is acid and in need of [li]me, and phosphorus fertilizers would also probably prove of value. The [fi]rst need of the soil, however, is the application of organic matter.

LINDLEY LOAM (65)

The Lindley loam is a minor type, covering only 3,264 acres or 0.7 percent [of] the total area of the county. It occurs in several small areas in association with the other soils of the Lindley series, along the Cedar and Wapsipinicon rivers and Big creek. There are no large areas of this type, the most extensive being found below Toddville and along Big creek south of Paralta.

The surface soil is a light grayish-brown or light brown, coarse silt loam or fine loam, extending to a depth of 8 to 10 inches. The subsoil at 20 inches is a brown, sandy, or silty clay loam and at 26 inches it becomes a sandy or gritty, brown or yellowish-brown clay. Stones and boulders occur both in the surface soil and subsoil. With this type there are included areas of brown or light grayish-brown, fine loam. It is rolling to rough in topography and the drainage is usually adequate. Only occasionally, where the subsoil is particularly compact, is tiling necessary.

A large part of this type is under cultivation, ordinary farm crops being grown. The crop yields, however, are in general rather unsatisfactory and this soil, like the other members of the Lindley series, is much in need of applications of farm manure and leguminous green manures in order to build it up in organic matter and nitrogen. It is acid and should receive the necessary application of lime. It is very low in phosphorus and would probably respond to phosphorus fertilization.

LINDLEY FINE SAND (135)

This is a very minor type, covering only 2,112 acres or 0.5 percent of the total area of the county. It occurs in small, scattered areas on the uplands along the Wapsipinicon and Cedar rivers, in association with the Carrington silt loam and the other soils of the Lindley series.

The surface soil is a light grayish-brown fine sand to a depth of 18 to 20 inches. The subsoil is a light brown fine sand. Pebbles and gravel are found scattered thruout the soil.

In the northern part, there are small, scattered areas of a variation of this type. This variation consists of a grayish-brown to dark brown, slightly loamy fine sand, extending to a depth of 10 to 15 inches. The subsoil is a brown or light brown, loamy fine sand or very fine sand, grading at 36 inches into a light brown fine sand. An area southeast of Troy Mills has been included with the Lindley fine sand, but it is not typical. The soil of this area is usually called ''blow sand'' and is subject to shifting under the action of the wind. The greater part of this area is in pasture or meadow, some if ic being timbered with oak and hickory.

In topography, the type is gently rolling to rolling, drainage is excessive and the type is usually drouthy. In a few areas where the soil is found in depressions and shows a heavier subsoil, drainage may be inadequate.

The Lindley fine sand is mainly kept in pasture, which is probably the most satisfactory treatment, since cultivation renders it subject to drifting. Some of the type is forested, chiefly with oak, elm and hickory. Truck crops are grown to some extent. The incorporation of large amounts of organic matter would be of value in reducing the blowing. Large amounts of farm manure should be applied and leguminous green manures would also be of value. The soil is acid and in need of lime. It is low in phosphorus and applications of phosphorus fertilizers would probably prove profitable. These latter treatments are especially needed if the soil is to be cultivated.

LINDLEY VERY FINE SANDY LOAM (137)

This soil is of very small occurrence, covering only 1600 acres or 0.4 percent f the county's area. It occurs in small areas on rather steep slopes or ridges, hiefly along the Cedar river. The surface soil is a grayish-brown, very fine andy loam, extending to a depth of 12 inches. The subsoil is a light grayish-rown, coarse silt loam, grading at 36 inches into a brown or light brown, gritty, eavy silt loam or silty clay loam. The drainage of the type is usually adequate. n some cases indeed, being excessive. Small areas in depressions may, however, e benefited by tiling.

Small areas of this type are forested, but the greater part is cultivated. ruck crops are grown on some areas successfully, especially near Cedar Rapids. he soil is particularly in need of organic matter to make it more productive nd liberal applications of farm manure are recommended. This material is articularly valuable in the case of truck farming. Leguminous green man-res would also be of value. The soil is acid and in need of lime, and phos-horus fertilizers would probably prove profitable, especially for the growth f truck crops.

TERRACE SOILS

There are nine terrace soils in the county, belonging to the Buckner, Bremer, udson and Calhoun series. These terrace soils as a whole cover 28,982 acres or .4 percent of the total area.

BUCKNER SILT LOAM (36)

This is the most extensive terrace type, covering 9,536 acres or 2.1 percent of he county's area. It occurs in numerous areas along the various streams. The argest area is found in the northeast part of the county, along Buffalo creek, outh of Prairieburg. Other large areas are found in the vicinity of Palo and long Indian creek, north of Marion. A large part of the city of Cedar Rapids outhwest of the river is located on this type.

The surface soil is a dark brown silt loam, 15 to 20 inches in depth. The sub-oil to a depth of about 30 inches is a grayish-brown, compact silt loam. Below hat point it becomes a light brown or yellowish-brown, gritty, silty clay loam, rading into a loam or fine sandy loam. The lower soil layers are sandy and uch gravel and coarse sand is also found thruout the soil section. Several areas hich are somewhat different from the typical Buckner, are included in this ype. These areas are usually characterized by a grayish-brown, friable silt loam urface soil. In topography this type is nearly level or gently undulating, but he drainage is usually adequate.

The Buckner silt loam is practically all cultivated, general farm crops being rown. Corn gives excellent yields and small grains also produce satisfactorily. he soil is acid and in need of lime, especially if legumes are to be grown. It ould be benefited by applications of farm manure and phosphorus fertilizers ould also prove of value for increasing crop yields.

BREMER SILT LOAM (88)

The Bremer silt loam is of minor occurrence, covering only 4,982 acres or 1.0 ercent of the county. The soil occurs most extensively in the southwestern part, in Fairfax and College townships, where it occupies the former wide channel of Prairie creek. Other areas of this type are found along the Cedar river and in other parts of the county on low terraces.

The surface soil is a dark brown or black heavy silt loam, 18 inches in depth. This is underlaid by a light grayish-brown, silty clay loam or silty clay, faintly mottled with brown, and at a lower depth, by a brown silty clay. In topography it is level to flat and in some instances drainage is inadequate and tiling would be of value.

Practically all of this soil is cultivated, corn being the principal crop grown. Small grains are less satisfactory, owing to their tendency to lodge. The soil is acid and in need of lime. It is not particularly well supplied with phosphorus and would probably respond to phosphorus fertilization. Small applications of farm manure might be used to advantage, but should be applied after the oats crop of the rotation.

JUDSON SILT LOAM (131)

This is a minor soil type, covering 3,712 acres, and with the light colored phase, which is small in extent, covers only 0.9 percent of the county's area. The most extensive development of this type is north of Palo, but there are several small areas in other parts of the county. It occurs in association with the Clinton and Tama silt loams, occupying a terrace position, separating the loessial uplands from the flood plains of the rivers. The soil is largely derived from the wash from the loessial uplands.

The surface soil of this type is a dark brown or nearly black, friable silt loam, 18 inches in depth. It is underlaid by a brown, friable, heavy silt loam or silty clay loam, grading into a light brown, friable, silty clay loam. In topography it is almost flat, with a slight slope towards the streams. It is usually well drained, but in some of the smaller areas with more compact subsoils, tiling is sometimes of value.

Practically all of this type is under cultivation, corn being the chief crop grown. Excellent yields are secured. Small applications of farm manure would be of value and eventually phosphorus fertilizers will be needed.

JUDSON SILT LOAM (Light colored phase) (132)

This phase of the Judson is of small extent, covering only 512 acres or 0.1 percent of the county's area. It is found in small areas one-half mile north of Cedar Rapids and northwest of Bertram.

The surface soil is a light, grayish-brown or light brown, friable silt loam, 10 to 12 inches in depth. This is underlaid by a light brown to dark brown or dark yellowish-brown, compact, gritty silty clay loam. In topography this phase is very much like the typical Judson, crop growth is very similar, and the needs of the soil are for lime, farm manure and eventually the use of phosphorus fertilizers.

BUCKNER LOAM (38)

The Buckner loam is a minor type, occupying 3,968 acres or 0.9 percent of the county's area. It occurs on the terraces along both the larger and smaller streams of the county. The most extensive areas are found along the Cedar river, where it occurs in association with the Buckner silt loam and sandy loam. Narrow strips of the type are found along the smaller streams.

The surface soil is a dark brown fine loam, extending to a depth of 10 to 20 inches. The subsoil is a grayish-brown or light brown loam. In some areas, the subsoil is a compact fine loam. Gravel and coarse sand are frequently found thruout this type. Variations from the typical Buckner are found southeast of Troy Mills, where the soil is only slightly above overflow and much coarse gravel is present on the surface. Along Buffalo creek south of Coggon, also, the soil is very open and porous and contains much coarse material at the surface. In topography this type is level to gently undulating and the drainage is adequate. In some cases where the soil is loose and impervious, it is inclined to be drouthy.

Practically all of the Buckner loam is under cultivation, corn and small grains being the chief crops grown. The soil is acid and should receive lime applications, especially for the best growth of legumes. Applications of farm manure are particularly valuable and where this material is not available, the use of leguminous green manures should be employed. The phosphorus supply is not high and phosphorus fertilizers would probably prove of value.

BUCKNER FINE SANDY LOAM (45)

This is also a minor type, covering 3,712 acres or 0.8 percent of the county's area. It is found chiefly on the terraces along the Cedar river, but there are rather extensive areas along the Wapsipinicon and Buffalo creek.

The surface soil of this type is a dark brown, friable, fine sandy loam, extending to a depth of about 20 inches. The subsoil is a brown or light brown, loose fine sandy loam or loamy fine sand. Some small areas of a very fine sandy loam are included in this type, owing to their small extent. Coarse gravel is usually found scattered thruout the soil and subsoil. In topography this soil is level to flat, but the natural drainage is good and, in fact, in some areas it is excessive and crops sometimes suffer.

Practically all of this type is under cultivation, corn being the chief crop grown. Small grains are also grown to some extent. The soil is acid and in need of lime. Applications of farm manure would prove particularly valuable to build up the soil in organic matter and nitrogen. The phosphorus content is low and applications of phosphorus fertilizers will probably prove of value.

BUCKNER SANDY LOAM (40)

The Buckner sandy loam is a very minor type, covering 1,216 acres or 0.3 percent of the county's area. It occurs in several small areas on the terraces along the Cedar river. There are also a few areas along the Wapsipinicon river and some of the minor streams.

The surface soil is dark brown, friable fine sandy loam or sandy loam, 20 inches in depth. The subsoil is somewhat lighter in color, usually a brown or light brown fine sandy loam or loamy fine sand. The topography of this type is nearly flat, but the drainage is adequate and in many instances the soil is droughty.

The type is practically all under cultivation, corn and small grains being the chief crops grown. The yields are much the same as on the Buckner fine sandy loam and the needs of the soil are similar. Thus, it is particularly in need of liberal applications of farm manure and would probably respond also to applications of leguminous green manures. It is acid and in need of lime, and phosphorus fertilizers would probably prove of value.

BREMER SILTY CLAY LOAM (43)

This is a very minor type, covering 1,152 acres or 0.3 percent of the total area of the county. It is found mainly along Prairie creek, but there are small, scattered areas along some of the minor streams. The surface soil is a black, silty clay loam, extending to a depth of about 18 inches. Below that point the soil is a grayish-black or black silty clay, faintly mottled with brown. At 24 inches, the subsoil passes into a grayish-yellow, heavy, compact silty clay, mottled with brown or light brown. Pebbles are found scattered thru the lower soil layers. In topography this type is level to flat and the drainage is poor. The use of tile and, in some cases, the installation of ditches, is necessary to carry away the excessive moisture.

The soil is practically all under cultivation, corn being the chief crop grown. Excellent yields are obtained in favorable seasons, when the soil is satisfactorily drained. The chief needs of the soil to make it more productive after drainage has been accomplished, is for the application of lime, the use of small amounts of farm manure to encourage the decomposition processes and eventually the addition of phosphorus fertilizers.

CALHOUN SILT LOAM (42)

This is of very small occurrence in the county, occupying only 192 acres or about 0.1 percent of the total area. It occurs in a few small areas on the terraces of the minor streams, chiefly Squaw creek and Buffalo creek.

The surface soil is a dark gray to brownish-gray, rather compact silt loam 8 to 10 inches in depth. The subsoil is a light brownish-gray or gray, friable silt loam, at 20 inches becoming a brownish-gray compact silty clay, mottled with brown. In topography this soil is level to flat and the drainage is very poor, due largely to the impervious nature of the subsoil.

Most of this type is under cultivation, general farm crops being produced. The soil is in need, first of all, of adequate drainage and it should then receive liberal applications of farm manure or leguminous green manures in order to build it up in organic matter and nitrogen. It is acid and should be limed, and the application of phosphorus fertilizers would probably prove of value.

SWAMP AND BOTTOMLAND SOILS

There are five swamp and bottomland types belonging in the Wabash, Cass and Sarpy series, and there is also a small area of muck. The total area in swamp and bottomland is 26,432 acres or 5.9 percent of the total area of the county.

WABASH SILT LOAM (26)

The Wabash silt loam is the most extensive of the bottomland types, covering 15,808 acres or 3.5 percent of the county's area. It is found along practically all of the streams, the largest areas occurring along the minor streams. Scattered areas are found, however, along the Cedar and Wapsipinicon rivers.

he surface soil is a black, friable silt loam to a depth of about 18 inches. ɔw that point the subsoil is a heavy, compact, silty clay loam, at the lower ths becoming black to dark gray in color and a compact silty clay in tex- ะ. Pockets of sand are found both in the soil and subsoil. Within this ɜ are included areas of the silty clay loam which are too small to be shown ırately. In topography this type is practically flat and the drainage is poor. s all subject to overflow.

ome areas are forested, especially those along the larger streams, but for most part there is little tree growth. The type is employed chiefly for grazing a good growth of blue grass is easily maintained. If this soil were to be ;ivated, it would need, first of all, to be thoroly drained and protected from rflow. It would then need small applications of lime and eventually phos- rus fertilizers. Small amounts of farm manure would also undoubtedly ve of value.

CASS LOAM (18)

'his is a minor type, covering 3,520 acres or 0.8 percent of the total area of the nty. It occurs mainly along the Cedar and Wapsipinicon rivers, some small as being found in the bottoms of some of the small streams.

'he surface soil is a dark brown fine loam or loam to a depth of 10 inches. ɜ subsoil is a light brown, loose sand and coarse sand. Many variations from ; type are found, pockets of loose sand occurring at various places thruout soil and subsoil. The surface soil is frequently shallow and the sandy soil comes close to the surface. In topography this soil is level to flat, but ıinage is adequate, owing to the sandy character of the subsoil.

This soil is used chiefly for pasture. If cultivated, it would require protection m overflow, the liberal application of farm manure or leguminous green nures, and probably also the addition of phosphorus fertilizers.

CASS SILT LOAM (106)

This is a minor type, covering 2,752 acres or 0.6 percent of the total area of county. The most extensive areas are found along the Cedar and Wapsip- con rivers and there are some small areas occurring in the bottoms of some the minor streams.

The surface soil is a dark brown or nearly black silt loam or fine loam under- d by grayish-brown or light brown loamy fine sand, grading into a loose fine ıd. Thruout the several areas of the type, there are many variations from ; typical. This type is level in topography and the drainage is adequate, ing to the open character of the subsoil. It is subject to overflow.

Most of this land is used for pasture, a large part being timbered with soft ıple, elm, birch, cottonwood, scarlet hawthorne and wild crab apple. A few ɜas which are less frequently overflowed are under cultivation and corn is ɜ chief crop grown. The soil, when cultivated, is in need of liberal applica- ns of farm manure and leguminous green manures, and will eventually need osphorus fertilizers.

CASS FINE SANDY LOAM (130)

This is a very minor type, covering 2,688 acres or 0.6 percent of the total area of the county. It occurs chiefly along the Cedar and Wapsipinicon rivers, the areas being small.

The surface soil is a dark brown, friable, fine sandy loam. At 8 inches, it becomes a brown or dark grayish-brown loamy fine sand, which at 20 inches passes into a light brown or light grayish-brown, loose fine sand. With this type there are included areas of the sandy loam which are too small to show separately. In topography, the type is level to flat, but it is well drained, owing to the open nature of the subsoil. In many places the drainage is excessive. It is subject to overflow.

This type is used mainly for pasture and much of it is forested. In a few areas less frequently flooded, the soil is cultivated, corn and small grains being produced. For satisfactory crop production, the soil should first of all be protected from overflow. It should then receive a liberal application of farm manure or leguminous green manures. It is acid and in need of lime, and phosphorus fertilizers will be needed in the near future.

SARPY FINE SAND (133)

This is a minor type, covering 1,280 acres or 0.3 percent of the county's area. It occurs in small areas along the Cedar and Wapsipinicon rivers.

The surface soil is a dark grayish-brown or brown loose fine sand, extending to a depth of 15 inches. The subsoil is a grayish-brown or light brown fine sand. There are many variations in texture from the typical soil. In many cases coarse sand is found thruout the soil section, and in some areas the soil is a fine sandy loam. A part of the area included with this type is of such a variable nature that it should really be called riverwash.

This soil is subject to overflow and is used mainly for pasture, but in many cases it supports only a poor growth of grass. Some of the areas are forested, chiefly with hawthorne, elm, crab apple, birch and willow. The type has little agricultural value and to be productive, should be protected from overflow, supplied with a liberal amount of farm manure, lime as needed, and a phosphorus fertilizer.

MUCK (21a)

There is a very small area of muck in the county, amounting to 384 acres or 0.1 percent of the total area. The largest area is found two miles northwest of Palo. Many small areas occur in various parts of the county. The surface of this material is dark brown or black in color and sometimes quite silty in character. At 8 inches, a black, compact, impervious, stiff silty clay is encountered and this grades at lower depths into a yellowish-drab or gray, sticky, silty clay, mottled with brown and reddish-brown. The areas of muck are found in depressions where organic matter has accumulated in large amounts and the drainage is very poor. The natural growth on these areas consists of marsh grass, smart weed and other aquatic plants.

Most of the muck is in pasture. It may be reclaimed by thoro drainage and will then support a good growth of many crops, preferably truck crops. It is very satisfactory for general farm crops until it has become more thoroly ɔmposed and drained. Crops like potatoes, tomatoes, etc., give good yields these areas. When drained and brought under cultivation, these areas of ɔk prove very productive and need little fertilization except that phosphorus ilizers will be required for any extensive crop growth.

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.

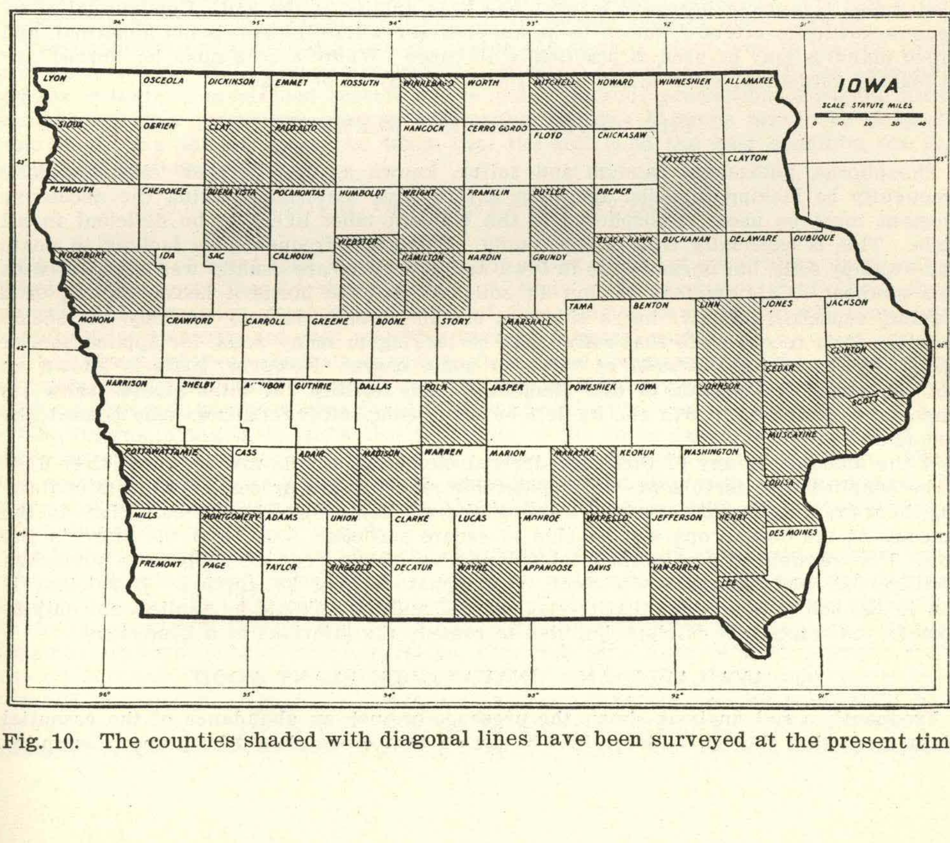


Fig. 10. The counties shaded with diagonal lines have been surveyed at the present time

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

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

PLANT FOOD IN SOILS

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

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

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

THE " SOIL DERIVED" ELEMENTS

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

If the amounts of any of these soil-derived elements in soils are very low, they need o be supplied thru fertilizers. If considerable amounts are present, fertilizers containng 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	Phos-phorus	Potass'm	Nitrog'n	Phos-phorus	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.

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*Bulletin 150, Iowa Agricultural Experiment Station.

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

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

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

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

MANURING

'here must always be enough humus, or organic matter, and nitrogen in the soil if isfactory crops are to be secured. Humus not only keeps the soil in the best physical dition for crop growth, but it supplies a considerable portion of nitrogen. An abund-e of humus may always be considered a reliable indication of the presence of much rogen. This nitrogen does not occur in a form available for plants, but with proper sical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter ich makes up the humus, is made usable by numerous bacteria and changed into ible and available nitrates.

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

'hree materials may be used to supply the organic matter and nitrogen of soils. ese are farm manure, crop residues and green manure, the first two being much more nmon.

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

'rop residues, consisting of straw, stover, roots and stubble, are important in keeping the humus, or organic matter content of soils. Table I shows that a considerable tion of the plant food removed by crops is contained in the straw and stover. On all ms, therefore, and especially on grain farms, the crop residues should be returned the soil to reduce the losses of plant food and also to aid in maintaining the humus itent. These materials alone are, of course, insufficient and farm manure must be d 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 lissouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions f the soils of the state are based on the geological forces which brought about the ormation of the various soil areas. The various areas are shown in the map, fig. 11.

With the exception of the northeastern part of the state, the whole surface of Iowa 'as in ages past overrun by great continental ice sheets. These great masses of ice ioved slowly over the land, crushing and grinding the rocks beneath and carrying along 'ith them the material which they accumulated in their progress. Five ice sheets in- aded Iowa at different geological eras, coming from different directions and carrying, ierefore, 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 tiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." 'wo of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, overing the north central part of the state. The soils of these two drift areas are quite ifferent in chemical composition, due primarily to the different ages of the two ice ivasions. The Iowan drift soil was laid down at a much earlier period and is some- 'hat poorer in plant food than the Wisconsin drift soil, having undergone considerable eaching 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 oils, vast accumulations of dust-like materials which settled out of the air during a eriod of geological time when climatic conditions were very different than at present. 'hese loess soils are very porous in spite of their fine texture and they rarely contain irge pebbles or stones. They present a strong contract to the drift soils, which are omewhat heavy in texture and filled with pebbles and stones. The three loess areas i the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by ifferences in texture and appearance, and they vary considerably in value for farming urposes. In some sections the loess is very deep, while in other places the underlying eached till or drift soil is very close to the surface. Th fertility of these soils and heir needs are greatly influenced, therefore, by their depth.

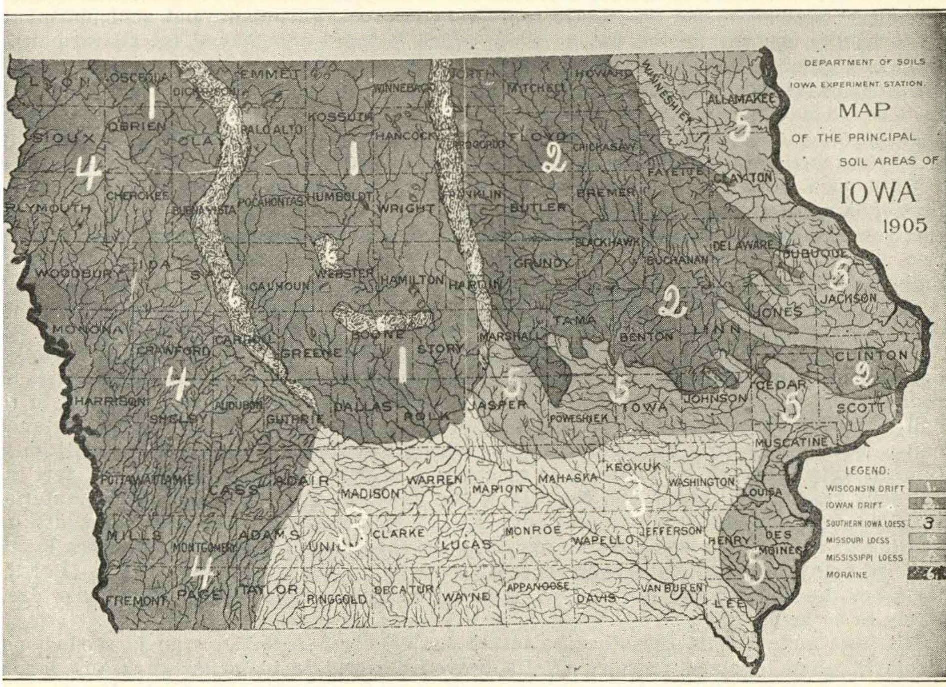

Fig. 11. May showing the principal soil areas in Iowa

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 little clay.

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

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always nore 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 ercent 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 ess than 25 percent very coarse sand, coarse sand and medium sand, much silt and a ittle clay; silt and clay 20 to 50 percent.

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

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

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

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 0 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 n surveying soils.

As has been indicated, the completed map is intended to show the accurate location nd 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 he 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 n 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 disances in the roads are determined by an odometer attached to the vehicle, and in the ield by pacing, which is done with accuracy. The directions of the streams, roads, railoads, 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 ampling both the surface soil and the subsoil. The boundaries of each type are then scertained accurately in the section and indicated on the map. Many samplings are requently necessary, and individual sections may contain several soil types and require nuch time for mapping. In other cases, the entire section may contain only one soil ype, 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 djoining area just mapped. Careful attention is paid to the topographic features of he area, or the "lay of the land," for the character of the soils is found to correspond ery closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil ype 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 heets are assembled and any variations or questionable boundaries are verified by urther 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.