SOIL SURVEY OF IOWA

BENTON COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
MECHANIC ARTS

Soils Section

Soil Survey Report No. 46
June, 1927
Ames, Iowa

May, 1927 Soil Survey Report No. 46

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Report No. 46--BENTON COUNTY SOILS

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

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

CONTENTS

BENTON COUNTY SOILS*

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

BENTON County is located in eastern central Iowa in the fourth tier of counties west of the Mississippi River and in the middle tier of counties in the state from north to south. It is partly in the Mississippi loess soil area and partly in the Iowan drift. Hence the soils of the county are partly derived from loessial material and partly from material of glacial origin.

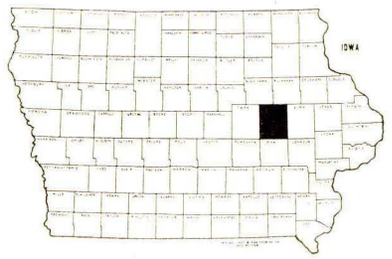

Fig. 1. A map showing location of Benton County.

The total area of the county is 712 square miles or 455,680 acres. Of this area 441,371 acres or 96.8 percent is in farm land. The total number of farms is 2,489 and the average size of the farms is 177 acres. The farms are operated by 1,046 owners, 507 relative renters, 684 renters, 236 both owning and renting, and 16 unclassified. The following figures from the Iowa Yearbook of Agriculture for 1925, show the utilization of the farm land in the county:

Acreage in general farm crops	296,065
Acreage in farm buildings, public highways and feed lots	22,074
Acreage in pasture	116,290
Acreage in waste land not utilized for any purpose	363
Acreage in farm woodlots used for timber only	1,948
Acreage in crop land lying idle	124
Acreage in crops not otherwise listed	4,877

THE TYPE OF AGRICULTURE IN BENTON COUNTY

The type of agriculture practiced in Benton County at the present time consists of a system of general farming, including the growing of corn and other general farm crops for feed and for sale, the raising of hogs, the raising and feeding of beef cattle, some dairying, and the raising and feeding of sheep.

Most of the general farm crops grown in the county are utilized on the farm for feeding purposes. From 60 to 80 percent of the corn is fed, the remainder being sold on the outside markets. Probably about half of the oats crop, on the average, is marketed, the remainder serving for feed. Wheat is a cash crop but it is not an important crop in the county and is not grown very extensively. The hay crops are all used for feeding purposes. The chief sources of income on the farms of the county are from the sale of hogs and other livestock, and from the marketing of the surplus corn and other grain crops.

There is not a large area of waste land in the county but some of the areas which are classified in this way, may be made productive by the adoption of

*See soil survey of Benton County, Iowa, by Clarence Lounsbury and J. A. Elwell of the U. S. Department of Agriculture and Bryan Boatman and T. H. Benton of the Iowa Agricultural Experiment Station.

TABLE 1. AVERAGE YIELD AND VALUE OF PRINCIPAL CROPS GROWN IN BENTON COUNTY, IOWA*

Crop	Acreage	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crop
Corn	147,786	33.49	50.6	7,477,972	$0.56	$4,187,644
Oats	94,011	21.29	44.0	4,132,231	0.32	1,322,313
Winter wheat	1,267	0.28	22.0	27,874	1.36	37,908
Spring wheat	150	0.03	18.0	2,700	1.30	3,510
Barley	2,733	0.62	32.0	87,456	0.57	49,849
Rye	494	0.11	20.0	9,880	0.80	7,904
Potatoes	527	0.12	71.0	37,417	2.35	87,929
Tame hay	44,613	10.11	1.3	57,997	13.50	782,959
Wild hay	862	0.19	1.0	862	10.50	9,051
Alfalfa	317	0.07	3.0	951	17.50	16,642
Pasture	116,290	26.34				

*Iowa Yearbook of Agriculture, 1925.

proper methods of soil treatment. General recommendations for the handling of such areas cannot be given as the causes for unproductivity are quite variable. Later in this report definite suggestions will be given regarding methods which may be followed in reclaiming certain unproductive areas in individual soil types in the county. Advice may be secured from the Soils Section of the Iowa Agricultural Experiment Station as to the most desirable treatment for any areas, where the conditions are more or less abnormal.

THE CROPS GROWN IN BENTON COUNTY

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

The most important crop both in acreage and value, is corn. In 1925, it was grown on over 33 percent of the total farm land of the county. Average yields of the crop, in that season, amounted to 50.6 bushels per acre. The principal variety grown is Reid's Yellow Dent. Most of the corn produced is used for feeding purposes, about 20 to 40 percent being marketed. Many farmers use much of the corn for silage.

The second crop in acreage and value is oats. In 1925, this crop was grown on 21.29 percent of the total farm land of the county. Average yields of the crop amounted to 44 bushels per acre. In some cases much larger yields are secured where conditions are particularly favorable. The principal varieties grown are Iowa 103, Iowa 105, Silvermine and Kherson. About one-half of the crop is sold from the farm, the remainder being utilized for feeding purposes.

Tame hay is the third crop of importance. It is chiefly a mixture of clover and timothy. Tame hay was grown in 1925, on 10.11 percent of the total farm land of the county. Average yields amounted to 1.3 tons per acre. Some timothy and some clover are grown alone. In 1925, 2,901 acres were being devoted to timothy which was grown for seed. Some areas of clover are also utilized for the production of seed. There is only a small acreage in wild hay in the county and the value of the crop is not of large significance.

Potatoes are a minor crop but they are grown on practically every farm, chiefly to supply the home demand. Average yields amount to 71 bushels per acre. Some of the potatoes grown are sold on the local markets.

Wheat is a minor crop, both the winter and spring varieties being grown, the latter, however, to a very limited extent. Yields of winter wheat amount to 22 bushels per acre, while the spring varieties yield about 18 bushels per acre.

A small amount of alfalfa is grown and very considerable yields of the crop are secured under favorable conditions. If the proper care is taken in the preparation of the seed bed, the selection of seed and the inoculation of the crop, its value is considerable.

Barley and rye are minor crops and are grown to a very limited extent. There is some buckwheat and flax grown. Soybeans are occasionally planted in the corn for hogging down.

On some of the sandy soils watermelons and cantaloupes are produced and disposed of on the local markets. Sorghum is grown to some extent for syrup. Tree fruits and small fruits are produced on practically all the farms but not on a commercial scale. Apples are the principal tree fruit. There are some cherries, plums, pears and peaches. Grapes and berries are grown to supply the home demand.

THE LIVESTOCK INDUSTRY IN BENTON COUNTY

The extent of the livestock industry in Benton County is indicated in the following figures taken from the Iowa Monthly Crop Report of July 1, 1926. The figures were secured from the January 1, 1926 estimates of the U. S. Department of Agriculture, Division of Crop and Livestock Estimates.

Horses	17,500
Mules	1,000
All cattle	62,600
Hogs	137,500
Sheep	6,600

The raising of hogs is the most important livestock industry in the county. On January 1, 1926, it was estimated that there were over 137,000 head of hogs on the farms of the county. The leading breed is the Poland China, followed by the Duroc Jersey, Chester White and Hampshire. Many of the herds consist of purebred animals. The raising of hogs provides the chief source of income on most of the farms.

Cattle are raised to some extent and there is considerable feeding of cattle from the western ranges. On January 1, 1926, there were 62,600 cattle on the farms, most of these being beef cattle. The Hereford, Aberdeen Angus and Shorthorn are the most common breeds. In general the herds are not purebred but there are some purebred herds in the county.

Dairying is practiced to only a limited extent and the breeds predominating are the Holstein, Guernsey and Jersey. There are a few dairies adjacent to the larger towns and the dairy products are sold directly in the towns. Cream is separated on the farm and sold to the creameries or to local buyers.

On many of the farms one or more colts are raised each year, the Percheron and Belgian being the most popular breeds. There are only a few mules in the county.

Sheep are kept on some farms especially on the rougher areas. The Shropshire is the leading breed.

Some poultry is kept on every farm, chiefly chickens with some ducks, geese and turkeys. The value of the poultry and poultry products, which are largely disposed of locally, is considerable on many of the farms.

THE FERTILITY IN BENTON COUNTY SOILS

Crop yields on the soils of Benton County in general are quite satisfactory, especially on the more extensive upland types which are gently undulating to slightly rolling in topography. Crop yields on the soils of the county may be increased, however, by the adoption of better methods of soil management.

Some of the soil types are in need of more adequate drainage in order to increase their productivity. On the uplands, the Clyde silt loam is in need of drainage. On the terraces, the Bremer soils will respond to drainage. The Wabash types on the bottoms need drainage. In the case of all these types and wherever poorly drained areas occur in any other types in the county, the installation of tile is the first treatment needed for the best crop yields.

Some of the soil types in the county are not well supplied with organic matter and applications of farm manure to these soils will prove of value in increasing crop yields. On practically all of the soils the use of farm manure is very desirable. Even on those soils which are darker in color and apparently better supplied with organic matter, the incorporation of farm manure will bring about large returns.

Where farm manure is not available in sufficient amounts to provide for a regular application to all the soils, the growing of well inoculated legumes and turning them under as green manures would be of very considerable value. Green manuring is a very desirable farm practice as a supplement to farm manure or as a substitute for that material. The thoro utilization of all crop residues will also aid in maintaining and building up the supply of organic matter in the soils of the county.

All of the soil types in the county show an acid reaction and hence it is indicated that they are in need of lime, for the best growth of general farm crops, and particularly of legumes. Farmers in the county should have their soils tested for lime needs and apply the amount required if they expect to secure a satisfactory growth of legumes. Frequently, large increases in the yields of general farm crops follow the use of lime, but the beneficial effects of lime are evidenced especially on the legume crop.

Many of the soils in the county are not very well supplied with phosphorus and it would seem that applications of a phosphate fertilizer would certainly be needed in the very near future. In many cases, it appears from experiments and from some farm experience that the use of a phosphate fertilizer would be of value at the present time. It is recommended that farmers test the needs of their own soils for phosphorus and that they determine, also, the relative value of acid phosphate and rock phosphate, by simple experiments which may be carried out quite easily.

There is apparently an adequate supply of nitrogen in most of the soils of the county at the present time to meet the immediate needs of crops. In some cases, however, the content of nitrogen is not large enough for the best crop growth. In such cases, the use of some fertilizing material supplying nitrogen is very necessary at the present time, and on all the soils it is important that any system of soil management which is adopted include the application of some nitrogen-containing fertilizing material in order that the supply of the element may be kept up in the soil. With the proper utilization of farm manure or the turning under of legumes as green manures, the nitrogen content may be increased and maintained in the soil without the use of expensive commercial fertilizers.

Complete commercial fertilizers are probably not necessary on the soils of this county, at least where general farm crops are grown. Where truck crops are produced, however, the use of such fertilizers may be of value. It would seem from the experiments carried out thus far that, for general farm crops, acid phosphate is quite as efficient in increasing crop yields and will be more desirable for use because it is less expensive.

Erosion occurs on some of the soil types in the county, the Clinton silt loam and the Lindley silt loam being particularly affected by this injurious action. Much washing of these types and the formation of deep gullies may occur. In some areas there is erosion of the Tama silt loam and particularly in the case of the shallow phase of this type, washing away of the surface soil has occurred to a considerable extent. Occasionally the Carrington silt loam and the other types of the Carrington series and of the Clinton and Lindley series, are affected by erosion. Wherever this destructive action occurs, the adoption of some method of preventing its injurious effects or of reclaiming the land from a gullied condition is very desirable.

THE GEOLOGY OF BENTON COUNTY

The early geological history of Benton County need not be considered in detail here inasmuch as none of the soil types found in the county at the present time are derived from the early geological deposits. The native bedrock material has been so deeply buried under the later deposits of glacial drift and loess, that there has been no effect of these early formations on the soils of the county.

During the glacial age, at least two great glaciers swept over the county, the earlier, the Kansan, covering the entire county and leaving behind a vast deposit of glacial drift or till, consisting largely of a blue clay, containing numerous boulders and much gravel and sand. The earlier topographic features of the county were largely obliterated by this glacier. The depth of this glacial material is extremely variable, ranging from a few feet in some places to several hundred feet in others. When weathered, the Kansan drift changes to a yellowish-brown or yellow to reddish-yellow in color and the incorporation of organic matter has brought about some darkening where the drift is exposed. The soils of the Lindley series are derived wholly or in part from the Kansan drift material. These types are found mainly in the southern part of the county.

The second great glacier, known as the Iowan, covered practically all of the

county and the deposit left by this glacier has buried the earlier Kansan drift to considerable depths thruout the entire northern part of the county. Only on the southern edge is the Kansan drift exposed. The Iowan drift is extremely variable in thickness, being much thinner on the tops of the ridges while in the older depressions the depth is considerable. The unweathered deposit is a bluish-gray or drab clay. Where it has been oxidized by weathering, the color has changed to a brown or yellowish-brown. It ranges in texture from a heavy clay to a sandy or gravelly clay. Pockets of sand and gravel are found and boulders of varying size occur over the surface and scattered thru the drift layer. The soils of the Carrington and Clyde series are derived from this Iowan drift material and there are several Carrington types in the county, varying considerably in texture in the surface soil.

Sometime after the Iowan drift deposit, in a later geological age, when climatic conditions were very different than at present, a layer of so-called loess was deposited by the wind over much of the area of the county. Loess is a fine silt-like material which has become dark brown to light brown in color, depending upon the conditions which have prevailed since its deposition. In the forested areas, the color of the surface soil is much lighter, while on the prairies there has been more of an accumulation of organic matter and the soil is darker in color. The depth of the loess deposit is extremely variable. Over one-half of the soils of the county are derived from this loessial deposit. The soils of the Tama, Clinton and Grundy series are of loessial origin.

Many of the terrace and bottomland types are derived from the loessial material from the upland. In the areas where the drift soils occur on the upland, there are admixtures of glacial till with the loess in the terrace and bottomland soils. In some areas the bottomland types are derived entirely from drift material.

PHYSIOGRAPHY AND DRAINAGE

In topography, Benton County is undulating to gently rolling, gentle slopes leading from the uplands between the stream courses down to the streams. There are alternate occurrences of moderately elevated areas and slight depressions. It is a topography characteristic of a normal, drift-covered prairie plain. The generally rolling to gently rolling topography is broken by the shallow valley of the Cedar River which flows thru the northeastern part of the county and by a part of the valley of the Iowa River, which crosses the extreme southwestern part of the county. Along some of the valley slopes, especially south of the Cedar River in Benton Township, there has been considerable erosion and the surface soil is rather rough and broken.

There is a variation from a typical topographic condition, formed by a series of chain like hills, one-half to one and a half miles in width, beginning in the forested areas in Monroe and Big Grove Townships and extending in a southeasterly direction south of Newhall, to the corner of Florence Township. These elevations are termed pahas. They are most strikingly developed south and southeast of Newhall, where they rise from 60 to 80 feet above the general plain.

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

SOIL MAP OF BENTON COUNTY

Thomas D. Rice, Inspector, Northern Division. Soils Surveyed by Clarence Lounsbury in charge and J. A. Elivell, U. S. Department of Agriculture and Bryan Boatman and I. H. Benton, Iowa Agriculture Experiment Station.

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

LEGEND

Drift Soils

- 83 — Carrington silt loam
- 32 — Lindley silt loam
- 3 — Carrington sandy loam
- 119 — Carrington sand
- 1 — Carrington loam
- 136 — Lindley fine sandy loam
- 84 — Clyde silt loam
- 4 — Carrington fine sandy loam

Loess Soils

- 120 — Tama silt loam
- 143 — Tama silt loam shallow phase
- 122 — Clinton fine sandy loam
- 80 — Clinton silt loam
- 64 — Grundy silt loam

Terrace Soils

- 75 — Waukesha silt loam
- 126 — O'Neill sandy loam
- 88 — Bremer silt loam
- 105 — Chariton silt loam
- 40 — Buckner sandy loam
- 43 — Bremer silty clay loam
- 108 — O'Neill loam
- 131 — Judson silt loam

Swamp and Bottomland Soils

- 26 — Wabash silt loam
- 48 — Wabash silty clay loam
- 49 — Wabash loam
- 19 — Cass sandy loam
- 18 — Cass loam
- 20 — Meadow
- 160 — Sarpy sand
- 21 — Peat

Scale: 1 Inch 2½ Miles

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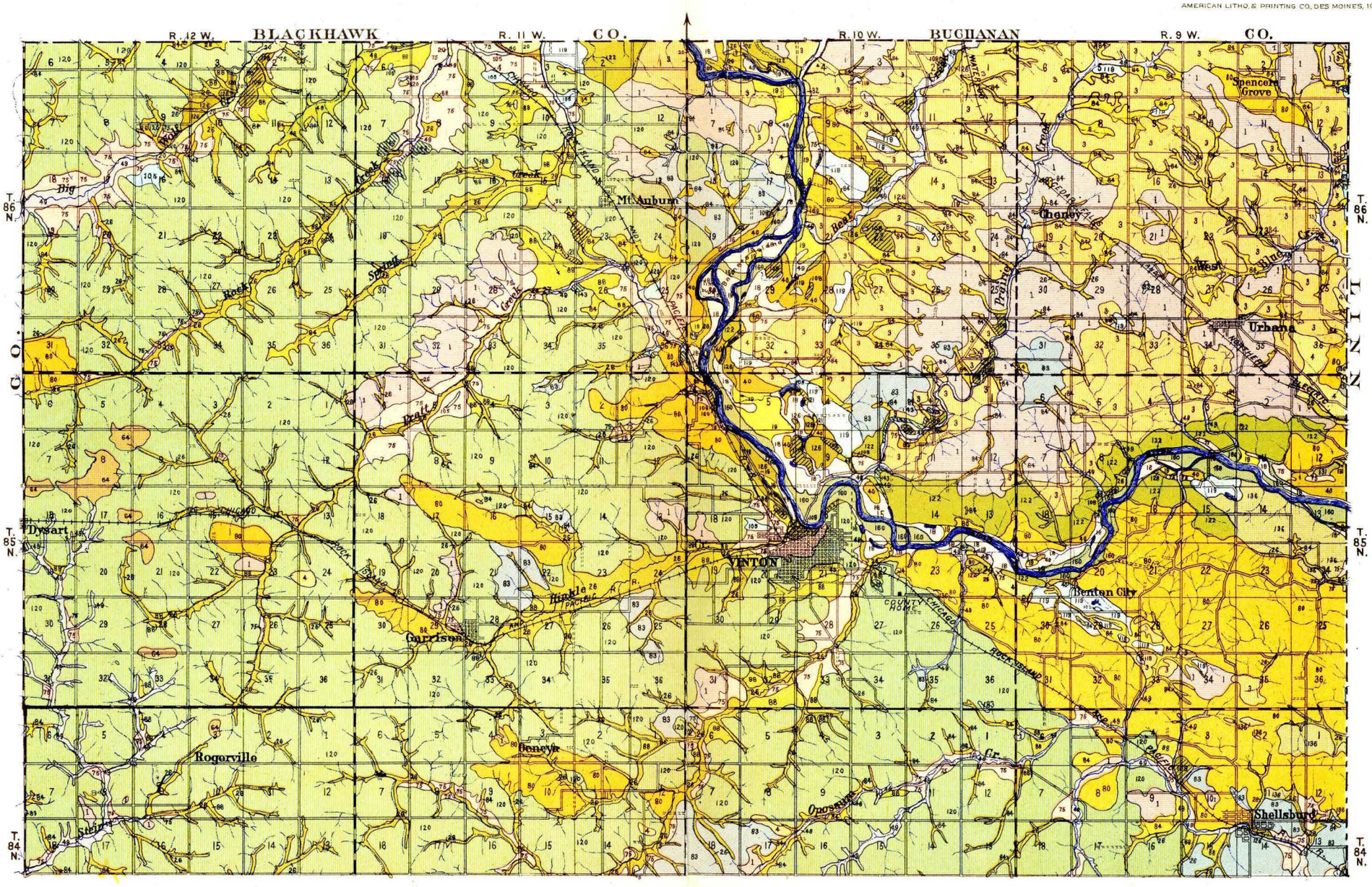

In the southwestern part of the county including the southern half of Iowa Township and the southern part of Leroy Township, and a small part of southern St. Clair Township, the topography in general is broken to rugged. The valleys are more deeply cut and branches of the streams extend back into all parts of the uplands. It is in this part of the county, that the earlier Kansan glacial deposit is exposed. In Big Grove and Monroe Townships there are two long, narrow areas, 60 to 70 feet above the surrounding plain. Here, the land is deeply cut by the washing action of water and in general it is quite rough in topography.

There is a belt of upland 2 to 4 miles in width north of the Cedar River and running parallel to it, where the surface soil consists of loose sand apparently formed by wind action. These ridges seem to extend in a general east and west direction altho they are very irregularly located.

There are narrow areas of bottomland soils along practically all the streams of the county. These bottoms are rarely more than a mile in width and where wider areas occur they consist mainly of second bottomlands which are above overflow from the present streams.

The drainage of Benton County is brought about mainly by the Cedar and Iowa Rivers and their tributaries. Most of the county is drained by the Cedar River, the chief tributaries of which are Wolf Creek, Rock Creek, Spring Creek, Pratt Creek, Hinkle Creek, Opossum Creek, Wild Cat Creek, Bear Creek and Dry Creek, draining the central portion of the county south of the Cedar River and the western and southeastern parts. North of the Cedar River the chief tributaries are Prairie Creek and Bear Creek. The Iowa River with its tributary, Pine Creek, drains the southwestern corner. Prairie Creek with its tributaries, Mud Creek and Morgan Creek drains the southern part of the county. The natural drainage system is very well developed as is indicated in the accompanying drainage map. Tributary streams from the two rivers and the larger creeks together with intermittent drainageways extend into practically all parts of the upland in the county. Drainage is quite adequate in most of the areas but there are some depressed areas in the upland where artificial drainage is needed.

THE SOILS OF BENTON COUNTY

The soils of Benton County are grouped into four classes, according to their origin and location. These groups are drift soils, loess soils, terrace soils and swamp and bottomland soils. Drift soils are those soils which have been formed from the deposits left by glaciers upon their retreat and they consist of material derived from various sources, usually including pebbles and boulders. Loess soils are fine dust-like deposits, made by the wind at some time when climatic conditions were different than at present. Terrace soils are old bottomlands, which have been raised above overflow by a depression in the volume of the stream by which they were formed, or by a deepening of the stream channel. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams and they are subject to more or less frequent overflow.

The total acreage and percent of the area of the county included in each of these four groups of soils are shown in table II. Slightly more than one-fourth of the area of the county, 26 percent, is covered by drift soils. The loess soils cover the major portion of the county, occupying 56.8 percent of the total area. Terrace soils occur to a limited extent, occupying 6.1 percent of the total area. Swamp and bottomland soils are more extensively developed, covering 11.1 percent of the county.

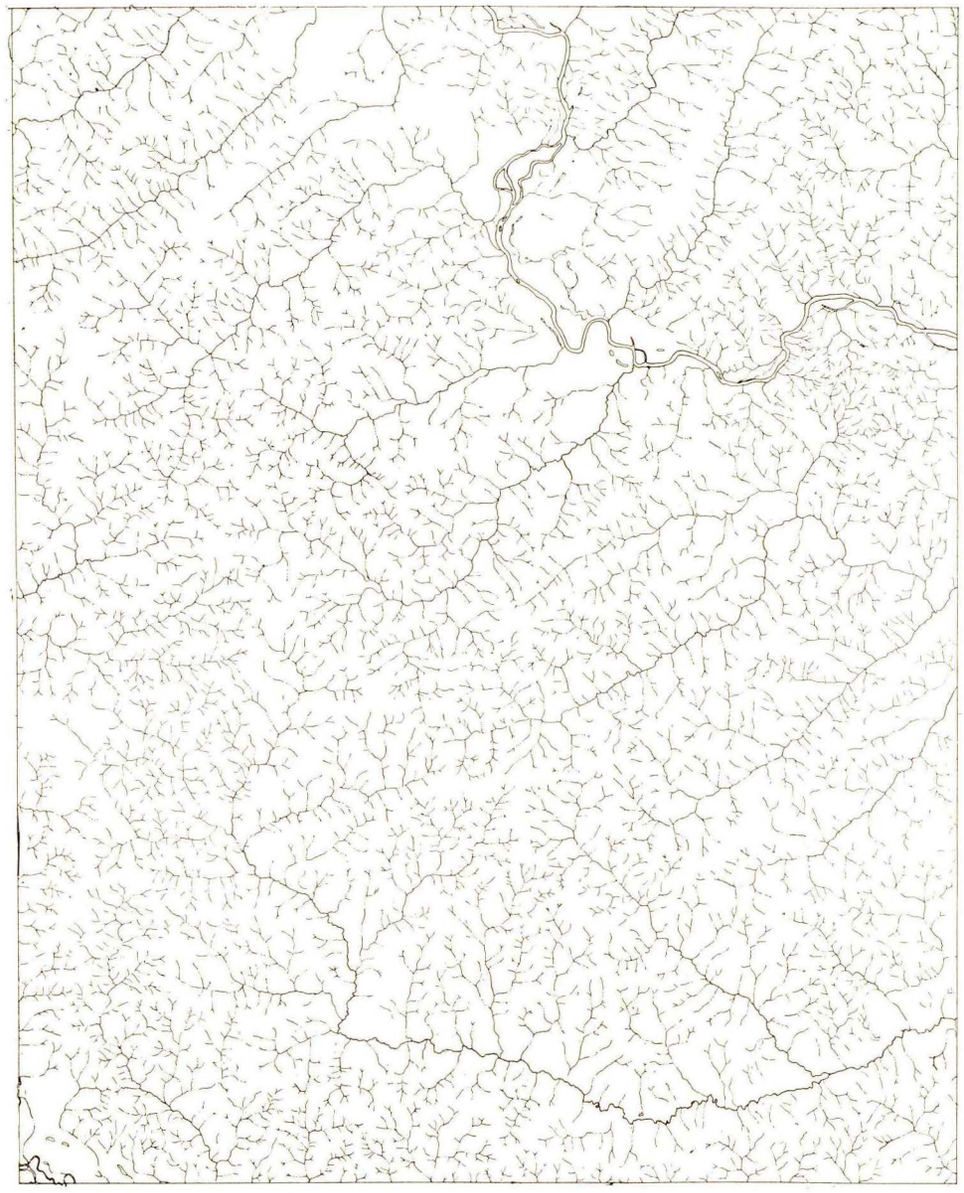

Fig. 2. Map of natural drainage system of Benton County.

TABLE II. AREA OF DIFFERENT GROUPS OF SOILS IN BENTON COUNTY

Soil Group	Acres	Percent
Drift soils	118,784	26.0
Loess soils	258,688	56.8
Terrace soils	27,200	6.1
Swamp and bottomland soils	51,008	11.1
Total	455,680	----

There are 26 individual soil types in the county and these with the shallow phase Tama silt loam and the areas of meadow and peat make a total of 29 soil areas. There are 8 drift soils, 5 areas of loess types, 8 terrace soils, and 8 areas of swamp and bottomland, including the meadow and peat. The areas covered by the individual soil types are shown in table III.

The Carrington silt loam is the most extensive drift soil in the county and the second largest individual type. It covers 11.8 percent of the total area. The Carrington sandy loam, the second drift soil, covers 5.2 percent. It is the fifth largest individual type. The Carrington loam covers 4.4 percent of the county. It is the sixth largest type. The Clyde silt loam, the fourth most extensive drift soil, covers 2.8 percent of the county. The remaining types are

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN BENTON COUNTY

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
83	Carrington silt loam	53,696	11.8
3	Carrington sandy loam	23,680	5.2
1	Carrington loam	19,840	4.4
84	Clyde silt loam	12,736	2.8
32	Lindley silt loam	3,392	0.7
119	Carrington sand	1,984	0.4
136	Lindley fine sandy loam	1,920	0.4
4	Carrington fine sandy loam	1,536	0.3
	LOESS SOILS		
120	Tama silt loam	216,968	48.4
143	Tama silt loam (shallow phase)	3,192	
80	Clinton silt loam	32,576	7.1
122	Clinton fine sandy loam	4,096	0.9
64	Grundy silt loam	1,856	0.4
	TERRACE SOILS		
75	Waukesha silt loam	13,056	2.9
88	Bremer silt loam	10,048	2.2
40	Buckner sandy loam	1,472	0.3
108	O'Neill loam	768	0.2
126	O'Neill sandy loam	768	0.2
105	Chariton silt loam	576	0.1
43	Bremer silty clay loam	384	0.1
131	Judson silt loam	128	0.1
	SWAMP AND BOTTOMLAND SOILS		
26	Wabash silt loam	37,952	8.3
49	Wabash loam	5,120	1.1
18	Cass loam	3,008	0.6
160	Sarpy sand	2,240	0.5
48	Wabash silty clay loam	1,088	0.2
19	Cass sandy loam	1,024	0.2
20	Meadow	448	0.1
21	Peat	128	0.1
	Total	455,680	----

of minor extent, covering less than one percent of the area. The Lindley silt loam covers 0.7 percent, the Carrington sand, 0.4 percent; the Lindley fine sandy loam, 0.4 percent; and the Carrington fine sandy loam, 0.3 percent of the county.

The Tama silt loam is the most extensive loess type in the county and the largest individual soil type. Together with the shallow phase which is very limited in extent, it covers almost half of the total area of the county, 48.4 percent. The Clinton silt loam, the second largest loess type and the fourth most extensive type, covers 7.1 percent of the area. The Clinton fine sandy loam is very minor in area, covering 0.9 percent. The Grundy silt loam covers only 0.4 percent of the county.

The largest terrace type in the county is the Waukesha silt loam, covering 2.9 percent of the total area. The Bremer silt loam is second in extent, covering 2.2 percent of the county. The remaining types of the Buckner, O'Neill, Chariton, Bremer and Judson series, cover only 0.3 percent or less of the total area of the county and all are of minor importance.

The Wabash silt loam is the most extensively developed bottomland soil and it is the third largest individual type in the county, covering 8.3 percent of the total area. The Wabash loam is second in area but very minor, covering only 1.1 percent of the county. The remaining bottomland types are minor in significance, covering less than one percent of the county, ranging from 0.6 of a percent to 0.1 percent.

There are certain rather definite relations indicated between the topographic features of the county and the soil types on the upland. The Tama silt loam and the Carrington silt loam occur on the gently rolling to rolling uplands. The Clinton soils and the Lindley types are found on the rough to broken areas in the rougher sections of the uplands, along the approaches to the streams and these soils are very considerably cut by the erosive action of water. The Clyde silt loam is found in depressions in the uplands and has a flat to depressed topography. The Grundy silt loam occupies more level areas on the loessial upland.

On the terraces and bottoms, the topographic features are very little developed. The Bremer types on the terraces, however, occupy the more level terrace positions, while the O'Neill, Waukesha and Buckner soils are in the higher positions. All the bottomland soils are level to flat and are in general apt to be poorly drained, especially in the case of the Wabash soils. The Cass and Sarpy types are adequately drained because of their loose sandy subsoils.

THE FERTILITY IN BENTON COUNTY SOILS

Samples were taken for analysis from all the soil types in the county except the Judson silt loam on the terrace, the Cass loam on the bottoms and the areas of meadow and peat. The soil types mentioned were not sampled because of their small extent. The areas of peat and meadow were not sampled because of their great variability, and because of the fact that analyses would mean little. All samplings were made with the greatest care that the samples should be representative of the soil types, and that variations due to local conditions or previous treatments should be eliminated. Samples were taken at three depths, 0 to 6 2/3 inches, 6 2/3 to 20 inches and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil respectively

The total phosphorus, total nitrogen, total organic carbon, total inorganic carbon content and the limestone requirements of the soil were determined. The official methods were used for the phosphorus, nitrogen and carbon and the limestone requirement determinations were made by the Truog qualitative test. The figures given in the tables are the averages of duplicate determinations on all samples of each type.

THE SURFACE SOILS

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

The phosphorus content of the soils of the county is extremely variable, ranging from 417 pounds per acre in the Lindley fine sandy loam to 3,124 pounds in the Wabash silty clay loam. There does not appear to be any relationship between the content of phosphorus in the soils and the various soil groups. The terrace and bottomland types are perhaps a little better supplied with the element than the upland soils. But this might be expected inasmuch as crop yields have been secured for a longer period of time on the upland

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

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
83	Carrington silt loam	1,057	3,260	42,826	------	8,000
3	Carrington sandy loam	673	2,380	28,067	------	8,000
1	Carrington loam	1,050	4,180	51,775	------	8,000
84	Clyde silt loam	1,697	8,560	106,982	------	6,000
32	Lindley silt loam	821	2,160	20,710	------	6,000
119	Carrington sand	646	580	9,025	------	8,000
136	Lindley fine sandy loam	417	1,200	11,717	------	6,000
4	Carrington fine sandy loam	457	1,080	13,897	------	8,000
	LOESS SOILS					
120	Tama silt loam	1,189	4,160	51,229	------	8,000
143	Tama silt loam (shallow phase)	1,023	4,100	47,687	------	8,000
80	Clinton silt loam	1,091	2,310	22,481	------	6,000
122	Clinton fine sandy loam	498	660	13,080	------	8,000
64	Grundy silt loam	1,293	5,840	71,940	------	8,000
	TERRACE SOILS					
75	Waukesha silt loam	1,468	4,320	51,230	------	4,000
88	Bremer silt loam	1,602	6,720	79,570	------	8,000
40	Buckner sandy loam	713	1,040	14,492	------	8,000
108	O'Neill loam	983	3,320	38,150	------	8,000
126	O'Neill sandy loam	875	940	13,625	------	8,000
105	Chariton silt loam	1,387	5,500	58,042	------	8,000
43	Bremer silty clay loam	1,333	6,240	85,565	------	8,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,468	6,540	88,835	------	8,000
49	Wabash loam	1,898	9,720	109,545	------	3,000
160	Sarpy sand	457	600	76,300	------	3,000
48	Wabash silty clay loam	3,124	6,460	71,395	------	6,000
19	Cass sandy loam	1,312	4,150	43,327	------	5,000

types and hence there has been a larger removal of the various plant food constituents. In general there seem to be wider variations in phosphorus content within the groups than there are among the various groups of soils.

Some relations are shown between the phosphorus content of the individual soils and the soil series. Thus, on the drift uplands, the Clyde silt loam is the richest in phosphorus of any of the types. The Carrington soils are, on the average, better supplied than the Lindley types. On the loessial uplands, the Tama and Grundy soils are better supplied with phosphorus than the Clinton. On the terraces, the Waukesha and Bremer soils are richer in this element than are the Buckner, O'Neill and Chariton soils. On the bottomlands the Wabash types are much richer in phosphorus than are the Cass and Sarpy soils. The differences in phosphorus content among these various soil series are undoubtedly a reflection of those characteristics which serve to distinguish the series. Thus there are differences in the color of the soil, in the topographic position and in the subsoil characteristics, which are reflected in the variations in plant food content. On the drift uplands, the Clyde soils are darker in color, level to depressed in topography and with heavy textured subsoils and they are higher in phosphorus. The Carrington soils are darker in color than the Lindley types, they are not so rolling to rough in topography and the subsoil conditions are heavier and they are better supplied with phosphorus than are the Lindley soils. On the loessial uplands, the Tama and Grundy types are darker in color than the Clinton soils; they are found on more level to gently rolling uplands and the subsoils are more impervious and hence there is more phosphorus present. Similarly on the terraces the Waukesha and Bremer soils are darker in color and have heavier subsoils than the other terrace types and they are richer in phosphorus. On the bottoms, the Wabash soils are richer than the Sarpy and Cass types, probably for the same reasons.

Some interesting relations are evidenced among the various soil types within the series. Here differences which are due to the variations in the texture of the soils are shown. On the drift uplands, the Carrington silt loam and Carrington loam are higher in phosphorus than are the sandy loams, the sands or the fine sandy loams of the same series. The Lindley silt loam is better supplied with phosphorus than is the Lindley fine sandy loam. On the loessial uplands, the Clinton silt loam is higher in the element than is the fine sandy loam of the same series. On the terraces, the Bremer silt loam and the Bremer silty clay loam do not show the usual relationships. The silt loam is somewhat higher in phosphorus than is the silty clay loam, probably due to some abnormal condition in the latter soil type. The O'Neill loam is higher in the element than is the O'Neill sandy loam. On the bottoms, the Wabash silty clay loam is much richer in phosphorus than are the other types of the Wabash series.

The data as a whole show quite definitely that there is a distinct relation between the phosphorus content in soils and the soil texture in practically all cases. Soils which are heavier in texture are richer in phosphorus than are those types which are coarser in texture, provided, of course, that the soils are in the same series. There are wider variations between the plant food content of soils in different series irrespective of texture but within the same series the textural condition is significant. Thus silty clay loams are higher than silt loams, silt loams are apparently better supplied than loams and the latter types are richer in the element than are sandy loams or other sandy types.

In general, it appears that the phosphorus content of the soils of the county is rather low and applications of phosphorus fertilizers will certainly be needed on these soils in the very near future. In many cases the supply is so low that it would seem certain that the use of a phosphorus carrier would be desirable at the present time. The experiments which are referred to later in this report indicate some large effects from the use of rock phosphate and acid phosphate.

There is considerable variation in the nitrogen content of the soils of the county, the amounts present ranging from 580 pounds per acre in the Carrington sand on the drift uplands up to 9,720 pounds in the Wabash loam on the bottomlands. There are no definite relations between the nitrogen content of the soils and the various groups of soils. The terrace and bottomland types are a little better supplied than the upland soils but there is no large difference.

There are certain differences in nitrogen content, however, which seem to reflect the characteristics which are used as the basis for the separation of the various soil series. Thus, on the drift uplands, the Clyde silt loam is much higher in this element than are the other types, while the Carrington soils are better supplied than the Lindley types. On the loessial uplands, the Grundy and Tama soils are better supplied than the Clinton. On the terraces, the Chariton, Waukesha and Bremer soils are better supplied with nitrogen than the other types. On the bottoms, the Wabash soils are better supplied than the Cass and Sarpy types. It would seem, therefore, that the color of the soil, the topographic conditions and the subsoil characteristics serve in a large measure to determine the nitrogen content of the soil. Those types which are dark in color, level in topography and with heavy subsoils, like the Clyde, the Grundy, the Bremer and the Wabash types, will naturally be higher in nitrogen.

There are some interesting correlations, also, between the textural differences in the soils and their nitrogen content. The Carrington silt loam and the Carrington loam are higher in nitrogen than are the sandier types. The Carrington loam is a little better supplied than the Carrington silt loam, which may be due to some abnormal feature connected with this particular sample. The difference, however, is not large. Both the loam and the silt loam are very much better supplied than are the sandy loam, the fine sandy loam or the sand. The Lindley silt loam is higher in nitrogen content than the fine sandy loam. The Clinton silt loam is better supplied with nitrogen than the fine sandy loam of the same series. The Bremer silt loam and silty clay loam contain practically the same amounts of nitrogen. The O'Neill loam is very much better supplied with the element than the O'Neill sandy loam. The Wabash silt loam and silty clay loam have about the same nitrogen content, both, however, contain less nitrogen than the Wabash loam. This is contrary to the usual relationship and probably may be attributed to some abnormality in the particular sample of Wabash loam. In general, it would seem that the nitrogen content of the soils in the county will vary quite definitely with the color, topography, subsoil character and the texture of the surface soils. On those

soils which are black in color, level in topography, with heavy subsoils, and where the surface soil is heavier or finer in texture, the largest amounts of nitrogen will ordinarily be found.

The supply of nitrogen in many of the soils of the county is apparently quite adequate for the needs of many crops. In a few cases, the content of nitrogen is low but in general the soils are fairly well supplied. Nitrogen must not be overlooked, however, in planning systems of permanent fertility for the soils of this county.

The most common and valuable fertilizer for returning nitrogen to land is farm manure. This material, as it is produced on the farm, should all be preserved and returned to the land in order to aid in maintaining the supply of nitrogen. Leguminous crops may be used as green manures in order to supplement the use of farm manure. The utilization of all crop residues likewise aids materially in keeping up the supply of nitrogen in the soils.

There are many variations in the content of total organic carbon or organic matter in the soils of the county. The range is from 9,025 pounds in the Carrington sand up to 109,545 pounds per acre in the Wabash loam.

Apparently the same relationships may be noted here as were mentioned in the case of nitrogen. Those soils which are darker in color, show a higher content of organic carbon in general. The types which are level to depressed in topography are better supplied with organic matter and those soils which have heavy subsoils are richer in that constitutent. Thus, the Clyde silt loam on the drift uplands is the richest in organic matter. The Carrington soils are better supplied, in general, than the Lindley types. The Tama and Grundy soils on the loessial uplands are higher in organic matter than the Clinton soils. On the terraces, the Chariton, Waukesha and Bremer types are the richest in this constituent, while on the bottoms, the Wabash soils are the highest in organic matter.

There is also a relationship to texture as was noted in the case of nitrogen. The heavier textured soils are, in general, better supplied with organic matter than are the fine textured types. Thus, ordinarily, the silty clay loams will be higher in organic matter than the silt loams, the latter will be better supplied than the loams and the loams will be higher than the sandy types. This general relationship holds true in most of the soils in Benton County where various textured types occur in the same series. There are some exceptions, however, and these variations are undoubtedly due to some abnormal condition connected with the particular sample which has been analysed. It may be noted that the Carrington silt loam and Carrington loam are higher than the Carrington sandy loam, and much higher than the Carrington fine sandy loam. The Carrington fine sandy loam is higher than the Carrington sand. The Lindley silt loam is higher than the Lindley fine sandy loam, the Clinton silt loam is better supplied than the fine sandy loam of the same series. The O'Neill loam is higher than the O'Neill sandy loam. On the bottoms, there are some discrepancies, the Wabash loam is higher in organic matter than the heavier textured soils, just as was noted in the case of nitrogen. Apparently this sample of Wabash loam was particularly abnormal. Ordinarily the silty clay loam and silt loam would be higher in organic matter than the loam.

While many of the soil types in the county are very well supplied with organic matter some of them are rather deficient in this constituent, and in some cases the addition of materials supplying organic matter is very necessary for the best growth of crops. The application of farm manure is particularly necessary on those soils where the organic matter supply is low, but the use of farm manure has proven of large value even where the supply is apparently adequate and the soils are rich and black in color. Where farm manure is not available for use or where the supply is inadequate, the turning under of leguminous crops as green manures is very necessary in order that the content of organic matter in the soil may be kept up. Thoro utilization of all crop residues is also very necessary in order to aid in keeping up the supply of organic matter in the soil.

The relationship between the total carbon content of soils or the supply of organic matter and the nitrogen content indicates something regarding the rate at which plant food in the soils is made available. When the relation between these two constituents is not at the best, there will be a slow production of plant food and crops will not be properly supplied. In some of the soil types in Benton County this relationship is very poor. Thus in the case of the Carrington sandy loam, the Lindley silt loam, the Lindley fine sandy loam, the Carrington fine sandy loam, the Clinton silt loam, the O'Neill loam, the Chariton silt loam and the Cass sandy loam the relationship between the ntrogen and carbon indicates that there is too slow a production of available plant food for the best supplying of the needs of crops. On these soils, the addition of farm manure will be particularly valuable as farm manure has the ability of stimulating the production of available plant food.

None of the soils of the county show any content of inorganic carbon and they are all acid in reaction. The lime requirement figures which are given in the table should be considered, however, as merely indicative of the lime needs of the individual soil types. There is a wide variation in the lime requirements of different soil types and even in different samples of the same soil type and hence the figures should be considered to indicate only roughly the requirements of the soils. It is very important that every soil be tested for its lime needs, before any application of that material is made.

The data given serve to emphasize very definitely the fact that the soils in this county are acid in reaction and all show a considerable lime requirement.

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 million pounds of subsurface soil and 6 million pounds of subsoil per acre.

It will be unnecessary to consider the analyses of these lower soil layers here in detail, inasmuch as the conclusions which have been drawn regarding the needs of the soils from the analyses of the surface soils are very largely confirmed by the analyses of the subsurface soils and subsoils.

There is evidence from these analyses that the soils are not very well supplied with phosphorus and that additions of phosphate fertilizers will certainly be needed. There is no reason for assuming that there will be any increase in the supply of phosphorus from the amount present in the lower soil layers. The use of a phosphate fertilizer on the soils of the county is, therefore, recommended.

The soils are not any too well supplied with nitrogen and organic carbon in some cases, while in many of the types there seems to be an adequate supply. It is important, however, that some means be taken to keep up the content of these constituents if the soils are to remain satisfactorily productive. The use of farm manure, leguminous green manures and the thoro utilization of all crop residues is very desirable in maintaining the supply of organic matter and in aiding in keeping up the nitrogen content of the soil.

The need of lime on the soils of the county is emphasized by the analyses of the lower soil layers and it should merely be repeated here that the soils of the county should all be tested for lime requirement and applications of lime should be made regularly, as needed, in order that the soils may be put in the best condition for the growth of general farm crops and particularly for the best growth of legumes.

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

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
83	Carrington silt loam	1,710	3,300	55,045	------	8,000
3	Carrington sandy loam	1,347	3,280	48,505	------	8,000
1	Carrington loam	1,724	3,760	49,595	------	8,000
84	Clyde silt loam	1,778	5,480	82,840	------	6,000
32	Lindley silt loam	1,239	1,680	15,805	------	6,000
119	Carrington sand	914	400	6,540	------	6,000
136	Lindley fine sandy loam	808	1,240	16,350	------	6,000
4	Carrington fine sandy loam	808	1,400	19,075	------	8,000
	LOESS SOILS					
120	Tama silt loam	2,002	6,000	75,755	------	8,000
143	Tama silt loam (shallow phase)	1,562	4,000	44,145	------	8,000
80	Clinton silt loam	1,791	2,020	20,437	------	5,000
122	Clinton fine sandy loam	834	440	9,810	------	8,000
64	Grundy silt loam	1,884	7,520	98,100	------	8,000
	TERRACE SOILS					
75	Waukesha silt loam	1,884	5,680	65,400	------	8,000
88	Bremer silt loam	1,966	2,000	86,110	------	8,000
40	Buckner sandy loam	1,426	1,440	24,525	------	8,000
108	O'Neill loam	1,966	5,000	59,950	------	8,000
126	O'Neill sandy loam	1,670	1,840	27,250	------	8,000
105	Chariton silt loam	996	2,280	25,070	------	8,000
43	Bremer silty clay loam	1,884	8,800	130,800	------	8,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	2,316	8,040	95,920	------	8,000
49	Wabash loam	3,286	12,640	137,885	------	3,000
160	Sarpy sand	618	240	5,450	------	3,000
48	Wabash silty clay loam	6,168	9,720	113,360	------	6,000
19	Cass sandy loam	1,332	1,820	20,982	------	2,000

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

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
83	Carrington silt loam	2,220	2,520	39,648	------	8,000
3	Carrington sandy loam	1,454	2,880	33,517	------	8,000
1	Carrington loam	1,657	2,400	29,430	------	7,000
84	Clyde silt loam	1,818	2,280	37,605	------	5,000
32	Lindley silt loam	1,980	1,440	16,350	------	6,000
119	Carrington sand	1,333	480	9,810	------	4,000
136	Lindley fine sandy loam	1,414	1,080	18,802	------	8,000
4	Carrington fine sandy loam	1,171	3,000	21,255	------	8,000
	LOESS SOILS					
120	Tama silt loam	2,638	4,840	59,132	------	8,000
143	Tama silt loam (shallow phase)	1,899	2,880	34,335	------	500
80	Clinton silt loam	2,968	2,100	22,890	------	8,000
122	Clinton fine sandy loam	2,019	1,920	17,985	------	8,000
64	Grundy silt loam	1,980	4,080	44,145	------	2,000
	TERRACE SOILS					
75	Waukesha silt loam	2,463	4,560	52,320	------	8,000
88	Bremer silt loam	2,139	5,160	67,035	------	8,000
40	Buckner sandy loam	1,697	840	21,255	------	8,000
108	O'Neill loam	1,857	2,520	35,152	------	8,000
126	O'Neill sandy loam	1,575	1,080	14,715	------	4,000
105	Chariton silt loam	1,980	3,000	32,700	------	8,000
43	Bremer silty clay loam	1,776	3,360	67,852	------	2,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,575	3,960	88,290	------	8,000
49	Wabash loam	4,200	9,720	150,420	------	2,000
160	Sarpy sand	606	------	6,540	------	3,000
48	Wabash silty clay loam	7,233	9,600	139,792	------	6,000
19	Cass sandy loam	1,352	600	13,897	------	1,250

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soil types from Benton County with the idea of determining something regarding the fertilizer needs of these soils. These experiments were carried out on the Carrington silt loam and the Tama silt loam, the two most extensive soil types in the county. In addition, greenhouse experiments on the Tama silt loam from Black Hawk County, the Carrington silt loam from Black Hawk County and from Linn County, the Clyde silt loam from Linn County and the Clinton silt loam from Linn County are included, inasmuch as these soils are the same as those occurring in Benton County and the results may be considered to indicate, therefore, what may be expected from the same fertilizer applications on the soils of Benton County.

These greenhouse tests have all been carried out according to the same plan and the treatments used are the same as those employed in the field experiments. Manure is added at the rate of 8 tons per acre, lime in sufficient amounts to neutralize the acidity of the soil, rock phosphate at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a complete commercial fertilizer, a standard 2-8-2 brand, at the rate of 300 pounds per acre. Wheat and clover were grown in all the pots, the clover

TABLE VII. GREENHOUSE EXPERIMENT, CARRINGTON SILT LOAM, BENTON COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	8.7	20.8
2	Manure	9.3	21.4
3	Manure+lime	10.8	23.7
4	Manure+lime+rock phosphate	11.2	25.7
5	Manure+lime+acid phosphate	11.0	27.5
6	Manure+lime+complete commercial fertilizer	11.7	29.4

being seeded about one month after the wheat was up. In some of the tests only the wheat yields are given while in others only the clover yields were secured.

RESULTS ON CARRINGTON SILT LOAM

The results secured in the greenhouse experiment on the Carrington silt loam from Benton County are given in table VII, the average yields of the crops on the duplicate pots of each treatment being shown. The application of manure increased the yield of wheat and also showed a beneficial effect on the clover. The use of lime with the manure increased both crops to a very appreciable extent. Rock phosphate with the manure and lime gave a further increase in the yields of the crops, the increase being quite definite in the case of the clover. With acid phosphate, very much the same increase was secured in the case of the wheat, but the clover was increased to a larger extent. Similarly, with the complete commercial fertilizer, the increase was very much the same on the wheat as in the case of the rock phosphate, but with the clover there was a larger gain in yield.

This experiment indicates the value of the application of manure to this soil. It shows that lime should be applied for the best growth, not only of the legume crop, but also because of the beneficial effect on the small grain crops. The application of a phosphate fertilizer would seem to be very desirable, as crop yields were increased in both cases. The acid phosphate seemed to be a little

Fig. 3. Clover on Carrington silt loam, Benton County.

Fig. 4. Wheat and clover on Carrington silt loam, Benton County.

preferable in the case of clover but the difference was not large. The complete commercial fertilizer gave a slightly larger effect than the phosphates in the case of clover but had about the same influence on the wheat crop.

RESULTS ON TAMA SILT LOAM

The results secured on the Tama silt loam from Benton County are given in table VIII. The beneficial effect of the application of manure to this soil is indicated by a slight increase in the yield of wheat and a very distinct increase in the yield of clover. The addition of lime with the manure increased the wheat yield slightly but brought about a very large increase of clover. Rock phosphate with the manure and lime gave an increase in the wheat and showed also a definite increase in the clover crop. The acid phosphate with the manure and lime gave about the same increase as the rock phosphate in both cases. The complete commercial fertilizer had about the same effect on wheat as did the phosphates. The yield in the case of the clover was not secured.

These data indicate the value of applications of manure and lime to the Tama silt loam. The use of manure on this soil is strongly recommended be-

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

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

Fig. 5. Clover on Tama silt loam, Benton County.

cause of the beneficial effect on the growth of general farm crops. Lime will be particularly valuable on the legume in the rotation, as is indicated by the very beneficial effect on the clover grown in these pots. The application of a phosphate fertilizer is very desirable, increases being secured on both the crops grown in this test. No choice can be made between the rock phosphate and acid phosphate however, as the increases were very much the same with both materials. The complete commercial fertilizer does not seem to be any more desirable for use than the acid phosphate or rock phosphate.

RESULTS ON TAMA SILT LOAM FROM BLACK HAWK COUNTY

The results secured on the Tama silt loam from Black Hawk county are given in table IX. The application of manure increased the yield of wheat in this

Fig. 6. Wheat and clover on Tama silt loam, Benton County.

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

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	12.00	8.0
2	Manure	12.65	31.0
3	Manure+lime	12.86	51.5
4	Manure+lime+rock phosphate	14.03	57.0
5	Manure+lime+acid phosphate	12.72	64 5
6	Manure+lime+complete commercial fertilizer	13.67	59.5

test and brought about a large increase in the clover. Lime with the manure showed little effect on the wheat but brought about a large gain in the case of the clover. The rock phosphate with the manure and lime increased the yield of wheat considerably and showed an increase in the case of clover. Acid phosphate showed no effect on the wheat but had a pronounced effect on the clover. The complete commercial fertilizer increased the wheat yields and the clover yields showing slightly less effect than the rock phosphate on the wheat and a somewhat smaller effect than the acid phosphate on the clover.

The results indicate the value of applications of manure, to this soil and they show that the use of lime may be very desirable for increasing the growth of the legume crop. Rock phosphate or acid phosphate will prove valuable on the type, sometimes the acid phosphate showing up in a larger way while in other cases the rock phosphate gives better results. The complete commercial fertilizer does not seem to be as desirable for use as the phosphates.

RESULTS ON CARRINGTON SILT LOAM FROM BLACK HAWK COUNTY

The results secured on the Carrington silt loam from Black Hawk County are given in table X. The beneficial effect of manure is very definitely shown in this test, the yield of wheat being very largely increased and the yield of clover being almost four times as large on the manure treated pot. Lime with the manure had no effect on the wheat but brought about a definite increase in the yield of clover. Rock phosphate with manure and lime showed little effect on either of the crops. Acid phosphate, however, increased the yield of wheat and showed a very definite increase on the clover. The complete commercial fertilizer showed larger effects on both crops than did the phosphates, having a particularly large effect on clover.

The results discussed earlier on the Carrington silt loam from Benton County

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

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	12.53	4.5
2	Manure	14.76	15.5
3	Manure+lime	14.67	22.5
4	Manure+lime+rock phosphate	13.93	21.0
5	Manure+lime+acid phosphate	15.22	28.5
6	Manure+lime+complete commercial fertilizer	16.75	36.5

TABLE XI. GREENHOUSE EXPERIMENT, CARRINGTON SILT LOAM, LINN COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of 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

are confirmed by these results on the same type from Black Hawk County. The value of manure on this soil is shown and the beneficial effects of applications of lime are definitely indicated. The use of a phosphate fertilizer is shown to be very desirable on the type. Acid phosphate seemed to be preferable to rock phosphate in this particular test. Definite conclusions as to their relative value should not be drawn, however, until tests are carried on individual farms. The complete commercial fertilizer showed up very well in this experiment. But, in general, acid phosphate gives quite as good and even more profitable returns than complete commercial fertilizers.

RESULTS ON CARRINGTON SILT LOAM FROM LINN COUNTY

The results secured on the Carrington silt loam from Linn County are given in table XI. Here again the large beneficial effects of manure are indicated on this soil. The yields of wheat and clover both showed very large gains from the application. Lime with the manure increased the yields of wheat and brought about a very large effect on the clover. The rock phosphate with the manure and lime had a slight effect on the wheat but gave a gain in the case of the clover. Acid phosphate showed a greater effect than the rock phosphate on both of the crops grown. The complete commercial fertilizer had about the same effect as the phosphates in the case of both crops.

Here again the addition of manure, lime and a phosphate fertilizer on the Carrington silt loam is apparently very beneficial. Whether rock phosphate or acid phosphate should be employed can only be determined by special tests. It would not seem that a complete commercial fertilizer is as desirable for use as acid phosphate. The value of manure and lime on this type is very definitely shown.

RESULTS ON CLYDE SILT LOAM FROM LINN COUNTY

The results secured on the Clyde silt loam from Linn County are given in

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

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

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

Pot No.	Treatment	Weight of 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

table XII. The large beneficial effect of manure on this soil type is indicated by the increase in the yield of wheat and clover, the effect on the clover being particularly noticeable. The yields on the pots receiving manure and lime were very abnormal and they are not given. The rock phosphate and acid phosphate showed very similar effects on the wheat and clover, the acid phosphate having slightly more influence. The complete commercial fertilizer had about the same effect as the acid phosphate on both crops.

It seems apparent that this soil type in spite of its dark color and apparently high organic matter content is benefited materially by the application of farm manure. The use of lime will certainly be needed, as the soil is acid in reaction. The value of a phosphate fertilizer is very definitely shown, acid phosphate proving slightly superior in this particular case. It does not seem from the data that the complete commercial fertilizer would be as desirable for use as acid phosphate inasmuch as it does not bring about any larger increases in crop yields.

RESULTS ON CLINTON SILT LOAM FROM LINN COUNTY

The results secured on the Clinton silt loam from Linn County are given in table XIII. Only the yield of wheat was secured in this test. The beneficial effect of manure on this soil is very definitely shown by the increased yield of wheat. Lime with the manure had no further beneficial effect. Ordinarily, however, the use of lime on this type is very desirable and will bring about very large increases in the yields of legumes. The grain crops are not ordinarily expected to show an increase from the use of lime. The rock phosphate and acid phosphate and complete commercial fertilizer all gave gains in the yield of wheat, the acid phosphate having less effect than the other materials. The rock phosphate gave the best results in this particular test. The differences, however, are not large enough to be significant.

It appears that the Clinton silt loam will respond in a profitable way to applications of manure. Certainly lime should be added to this type when it is acid in order to secure the best growth of legumes. Increases may also frequently be secured from other crops grown on the soil when it is limed. The use of a phosphate fertilizer would seem to be very desirable. Whether acid phosphate or rock phosphate should be used can only be determined, however, by tests on individual areas. The use of a complete commercial fertilizer cannot be recommended unless tests are carried out in comparison with acid phosphate and definite value from the treatment is secured.

FIELD EXPERIMENTS

There is one field experiment in Benton County but it has not been under way for a sufficiently long period of time for the results to be of significance.

Fields are under way, however, in different counties on some of the same soil types which occur to a large extent in Benton County. The results secured in these field tests will be included here, inasmuch as they indicate quite definitely the results which may be expected from the use of the same fertilizing materials on the soils here. The results of the experiments on the Carrington silt loam on the Calamus Field in Clinton County, on the Tama silt loam on the Hudson Field in Black Hawk County, on the Carrington loam on the Jesup Field in Black Hawk County, on the Carrington silt loam on the Low Moor Field in Clinton County, on the Clinton silt loam on the Princeton Field in Scott County, on the Carrington silt loam on the Springville Field in Linn County and on the Carrington loam on the Waverly Field in Bremer County are all given. The results secured serve to indicate in a rather definite way the needs of the same soils in Benton County, and they show the responses which may be expected from certain fertilizer treatments on the same types in this county.

These field experiments have all been located on land which is representative of the particular soil type. The plots are 155 feet 7 inches by 28 feet or one-tenth of an acre in size. The location of the plots is fixed permanently by corner stakes. Precautions are taken in the application of the fertilizers and in the securing of the yields to insure the accuracy of the results.

In each field there is included a test under the livestock system of farming, using manure as the basic treatment and under the grain system, using crop residues in place of manure. The other fertilizing treatments which are tested, include rock phosphate, acid phosphate, and a complete commercial fertilizer. Limestone is applied to the soils when they are acid, as a basic treatment in addition to the manure or the residues. The manure is used at the rate of 8 tons per acre once in four years. The crop residues treatment includes the turning under of the second crop of clover, and the plowing under of the corn stalks. Occasionally the entire crop of clover is plowed under. In some cases only the seed of the crop is removed and the remainder is turned under. The corn stalks are cut with a stalk cutter or disc and turned under. Limestone is applied in sufficient amounts to neutralize the acidity of the soil. Rock phosphate is added at the rate of 2,000 pounds per acre once in a four-year rotation. Beginning in 1925, 1,000 pounds per acre of rock phosphate are being applied every four years. Acid phosphate is applied at the rate of 150 pounds per acre annually and a 2-8-2 complete commercial fertilizer is added at the rate of 300 pounds per acre annually. Since 1922 a 2-12-2 complete commercial fertilizer has been employed instead of the 2-8-2, 202 pounds being used, this amount supplying the same amount of phosphorus as that added in the 150 pounds of acid phosphate.

THE CALAMUS FIELD

The results secured on the Carrington silt loam on the Calamus Field in Clinton County are given in table XIV. This experiment was begun in 1914

TABLE XIV. FIELD EXPERIMENT, CARRINGTON SILT LOAM, CLINTON COUNTY CALAMUS FIELD

Plot No.	Treatment	1915 Wheat bu. per A. (1)	1916 Corn bu. per A.	1917 Oats bu. per A.	1918 Clover tons per A. (2)	1919 Clover tons per A. (3)	1920 Corn bu. per A.	1921 Corn bu. per A.	1922 Oats bu. per A. (4)	1923 Corn bu. per A. (5)	1924 Oats bu. per A.	1925 Clover tons per A.	1926 Corn bu. per A.
1	Check	15.9	32.9	28.8	1.45	0.58	57.5	36.0	35.9	38.8	39.2	1.10	53.4
2	Manure	26.1	46.7	54.2	3.04	0.74	65.2	43.5	45.4	47.3	50.4	1.52	57.8
3	Lime	18.5	47.6	35.6	2.44	0.92	63.2	49.5	43.6	42.1	57.9	1.51	61.2
4	Check	19.5	44.1	35.6	2.09	0.70	54.5	39.6	37.2	38.1	50.1	1.10	49.5
5	Manure+lime	24.0	55.5	55.9	3.39	0.74	75.7	51.0	51.8	45.2	60.2	1.86	59.6
6	Manure+lime+ rock phosphate	24.3	60.8	91.6	4.39	1.22	85.1	52.5	63.4	61.8	76.2	2.87	70.4
7	Check	21.2	42.2	37.1	3.07	0.90	58.2	44.4	36.3	38.6	54.4	1.31	52.0
8	Manure+lime+ acid phosphate	27.5	61.7	77.8	5.18	2.11	70.4	57.3	57.5	52.5	72.6	2.79	60.6
9	Manure+lime+ complete commercial fertilizer	31.9	63.3	86.6	4.35	1.66	82.2	59.4	66.1	54.3	74.4	2.69	68.9
10	Check	20.6	30.1	32.3	1.47	0.52	47.9	33.3	41.4	29.0	49.4	0.89	37.2

1. Winter wheat.
2. First cutting, clover only.
3. Plot 5 spotted with gopher holes caused low yields.
4. Drought in May, thin stand.
5. Frost on September 14, damaged checks but not phosphate plots.

and yields have been secured on these plots for 12 years. The application of manure has proven to be particularly valuable on this soil. Increases in crop yields have been secured every season and, in some cases, the increases have been very large, as for example on the corn in 1916, on the oats in 1917, on the clover in 1918, and on the oats in 1924. The effect was also very considerable on the first crop of wheat in 1915. The use of lime alone on this soil exerted a beneficial effect in most seasons, in some cases having a very large influence on the crop. Lime with manure brought about increased yields in practically all cases over those secured on the plots treated with manure alone. The effect of the lime appeared particularly on the corn in 1916, on the clover in 1918, on the corn in 1920, and in 1921, on the oats in 1924 and on the clover in 1925.

The rock phosphate supplied with the manure and lime brought about increased crop yields in all seasons. In most cases the increases were very large. The yield of oats in 1917 was enormously increased by the application of the rock phosphate. The clover in 1918 showed a ton increase from the use of the rock phosphate. The clover in 1919 was also increased to a large extent and in many of the other seasons very considerable increases were evidenced on the corn and oats, as for example the increase in the oat crop in 1924. In 1925 again there was over a ton increase in the yield of clover and in 1926 the corn was increased 11 bushels. Acid phosphate applied with the manure and lime showed even greater beneficial effects on the crops grown in some seasons while in other cases the effect was not so large. There was less influence on the oats

in 1917, on the corn in 1920, on the oats in 1922 and on the corn in 1923. There was less effect likewise on the oats in 1924, on the clover in 1925 and on the corn in 1926, but the differences in these last three cases were not very large except in the case of the corn in 1926. Larger effects were evidenced on the clover in 1918 and in 1919, and also on the wheat and corn in 1915 and 1916. The complete commercial fertilizer showed slightly larger effects than the acid phosphate in some cases but brought about smaller increases in many other instances. The differences were not very large in most cases.

These results show the very large value of applications of manure on this soil type. They indicate further that the use of lime will be very desirable when applied with manure. The value of a phosphate fertilizer is very clearly shown, in fact there are most striking increases in crop yields both from the use of acid phosphate and rock phosphate. The complete commercial fertilizer did not seem to be any more effective in increasing the crop yields than did the phosphates.

THE HUDSON FIELD

The results secured on the Tama silt loam on the Hudson Field in Black Hawk County are given in table XV. The value of manure on this soil is evidenced by the results secured on the various crops grown on this field. Increased yields

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

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

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

were secured in every season from the use of manure, and, in many cases, the increases were very large. The application of lime with the manure brought about increases in crop yields in every case, the legume crop showing particularly large benefits from the application of the lime.

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

The crop residues showed little effect on the yields, increases being noted in one or two cases. Lime with the crop residues increased the crop yields in every season showing large results on the clover and timothy in 1925 and 1926. Beneficial effects were also evidenced on the oats and corn in several seasons. Rock phosphate applied with the crop residues and lime brought about increases in crop yields in several seasons. In a few cases no gains were noted. Acid phosphate with the crop residues and lime showed very similar effects to those brought about by the rock phosphate, the increases being somewhat more pronounced in some seasons but not so definite in other cases. The complete commercial fertilizer had a greater effect than the acid phosphate in several cases, particularly on the clover and timothy in 1925 and 1926. In several other seasons, there was less effect evidenced than from the phosphate.

The Tama silt loam apparently will respond in a very large way to applications of manure and liberal amounts of this material should be applied in order to secure the best yields of general farm crops. The use of lime with manure is very desirable as the type is acid in reaction and the best growth of legumes will not be secured until lime is applied. Increases in the yields of other farm crops also result from the use of lime. The application of a phosphate fertilizer is very desirable on this soil. Whether acid phosphate or rock phosphate should be employed cannot be definitely determined from this test. The use of a complete commercial fertilizer cannot be recommended on this soil as it does not seem to bring about any larger increases in crop yields than are occasioned by the use of a phosphate.

THE JESUP FIELD

The results secured on the Carrington loam on the Jesup Field from Black Hawk County are given in table XVI. The application of manure to this soil proved very valuable as indicated by the increase in crop yields secured in practically all seasons on the plots receiving manure. The largest beneficial effects were noted on the clover in 1919, on the corn in 1921, on the corn in 1922 and on the corn in 1926. The use of lime with the manure increased the crop yields in practically all seasons, very large increases being noted on the clover in 1920, on the corn in 1921 and on the oats in 1923.

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

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

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

The rock phosphate with the manure and lime showed small increases in crop yields in several seasons but had a large effect on the corn in 1926. This was the only year when the rock phosphate brought about a very pronounced crop increase. Acid phosphate with manure and lime showed increases in several seasons which were very definite. Thus the clover in 1919 and 1924 was very largely increased as well as the corn in 1926. In several of the other seasons, the acid phosphate showed no greater effect than the rock phosphate. The complete commercial fertilizer gave larger effects than the acid phosphate in several seasons, particularly on the clover in 1919, the clover and timothy in 1920 and the corn in 1921 and 1922. In the later seasons, however, 1923, 1924 and 1926 there was less effect from the complete fertilizer than was brought about by the acid phosphate.

The crop residues showed little effect on the yields, giving increases only in a few cases. Lime with the residues increased the crop yields to a small extent in one case. In the remaining seasons there was no evidence of a beneficial effect from the lime. The rock phosphate with the crop residues and lime increased the yields very considerably in several seasons but in other cases the benefits were small. The acid phosphate with the crop residues and lime showed much larger effects than the rock phosphate in several cases, while in other seasons the yields were very much the same as those brought about with the rock phosphate. The complete commercial fertilizer had a larger effect than the acid phosphate in practically every season. The differences in general were not very large, however.

These results as a whole indicate that the Carrington loam will respond very definitely to applications of manure and liberal amounts of this fertilizing material should be applied. The type is acid in reaction and a response to the use of lime would naturally be expected. Large increases in the legume crops are shown when lime is employed. Occasionally other crops are also very largely increased by the use of lime. The addition of a phosphate fertilizer seems to be of value on this soil, acid phosphate apparently giving somewhat better results than rock phosphate at least when used with manure and lime.

THE LOW MOOR FIELD

The results secured on the Carrington silt loam on the Low Moor Field in Clinton County are given in table XVII. The beneficial effect of manure applied to this soil is evidenced by the increased crop yields secured in every season. In some cases very large increases were noted as on the clover and timothy in 1919, on the corn in 1922 and on the corn in 1923. Lime applied with manure

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

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

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

brought about further increases in crop yields in every case. The clover and timothy crop showed the largest beneficial effect but increases which were quite definite were also secured on the other crops grown on the field.

The use of rock phosphate with the manure and lime gave very considerable increases in the yields of crops in most seasons. In one or two cases, no increases were noted. Acid phosphate with the manure and lime had larger effects than the rock phosphate in practically all cases. The differences, however, were not very large. The complete commercial fertilizer gave very much the same effect as the acid phosphate, being slightly better in some seasons and having a lesser effect in other cases.

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

These data in general serve to confirm those secured on the same soil type on the Calamus Field from Clinton County. They indicate the value of applications of manure on this soil. The type is acid and will respond readily to applications of lime particularly for the legume crops. The use of a phosphorus fertilizer is very necessary on this soil in order to secure the best crop yields. In the experiments reported here acid phosphate seems somewhat preferable but rock phosphate also gave very good results and, in some cases, had larger effects than acid phosphate.

THE PRINCETON FIELD

The results secured on the Clinton silt loam on the Princeton Field in Scott County are given in table XVIII. The large beneficial effect of manure on this soil type is evidenced by the increased crop yields secured in practically all seasons. In some cases very large increases were noted, while in other seasons the influence was not as large as might have been expected. The use of lime with manure increased the yields of the crops grown in every season, the clover crop showing the largest effect, as would be expected. Considerable increases were also secured, however, on the corn, oats and wheat crops grown in the rotation.

The application of rock phosphate with the manure and lime increased the crop yields in practically all cases. In some seasons very large increases were noted. The acid phosphate with the manure and lime showed no larger effects than the rock phosphate in most cases. In one or two seasons the effect was very

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

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

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

much larger, as for instance on the oats in 1924 and on the clover in 1926, but in the other seasons the results from the two phosphates were very similar. The complete commercial fertilizer had a slightly larger effect than the acid phosphate in several cases but in general the differences were not large enough to be of significance.

The crop residues had little effect on the yields secured in the different seasons, increasing them slightly in some cases. Lime with the crop residues brought about gains in crop yields in all seasons, the effect being particularly evidenced on the clover crop. Other crops grown, however, showed large effects in certain seasons as, for example, the corn in 1920 and the wheat in 1925. The rock phosphate applied with the crop residues and lime increased the yields of the crops in practically all cases. In one or two instances, very large gains were noted as was the case with the clover in 1926. The acid phosphate with the crop residues and lime showed slightly larger effects than the rock phosphate in several cases, but in most instances the differences were not very significant. Only on the oats in 1924 was there a very definite superior effect from the acid phosphate. The complete commercial fertilizer showed better results than the acid phosphate in several seasons but, in other cases, the differences were not large enough to be of significance.

The Clinton silt loam will certainly respond readily to applications of manure, lime and a phosphate fertilizer. A liberal application of manure to this type is very desirable as the soil is low in organic matter and needs to be built up in this constituent. The use of lime is necessary as the type is acid in reaction, if the best growth of legumes is to be secured. Whether rock phosphate or acid phosphate should be employed can only be determined by special tests under individual soil conditions. The use of a complete commercial fertilizer on this type may be of value in some cases. The results thus far secured from tests, however, have indicated that acid phosphate may be quite as desirable for use and even more profitable.

THE SPRINGVILLE FIELD

The results secured on the Carrington silt loam on the Springville Field series I in Linn County are given in table XIX. The beneficial effect of manure on this soil is evidenced by the results secured in this experiment. Considerable increases in crop yields were secured from the use of manure in practically all seasons. In some cases the crops were increased to a large extent, as for example the corn in 1923. The application of lime along with manure increased the crop yields in most cases. In several seasons there were very large benefits from the use of this material as for example on the corn in 1920 and the oats in 1925.

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

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

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

The rock phosphate with the manure and lime showed very definite increases in crop yields in practically all seasons. In some cases gains were very striking as for example on the clover in 1922 and on the corn in 1923. The acid phosphate with the manure and lime gave larger increases than the rock phosphate in several cases but in some instances the rock phosphate proved somewhat superior. The differences were not very great, however, in any instance. The complete commercial fertilizer showed slightly smaller effects than the acid phosphate in some seasons but in other cases had a somewhat larger effect. No large differences in the yields, however, were noted.

The crop residues brought about slight increases in crop yields in most seasons. Lime with the crop residues exerted a beneficial effect in several cases, the largest influence being noted on the oats in 1925. Rock phosphate with the crop residues and lime had a beneficial effect on the crop yields in all but two cases. In some seasons the influence was very large, as for example on the clover in 1922 and the corn in 1923. The acid phosphate with the crop residues and lime showed a larger effect than the rock phosphate in several seasons but in other cases the influence was very much the same as that exerted by the rock phosphate, and in one case there was a very pronounced difference in favor of the rock phosphate. The complete commercial fertilizer showed less results than the acid phosphate in many seasons, and in two cases where a larger influence was exerted the difference was not great enough to be significant.

TABLE XX. FIELD EXPERIMENT, CARRINGTON SILT LOAM, LINN COUNTY, SPRINGVILLE FIELD, SERIES II

Plot No.	Treatment	1919 Corn bu. per A. (1)	1920 Oats bu. per A. (2)	1921 Clover tons per A.	1922 Corn bu. per A.	1923 Corn bu. per A. (3)	1924 Oats bu. per A. (4)	1925 Clover tons per A. (5)	1926 Corn bu. per A. (6)
1	Check	61.1	41.1	1.16	62.6	32.0	----	0.87	40.0
2	Manure	66.0	46.8	1.42	76.0	40.0	----	0.90	41.0
3	Manure+lime	66.2	48.8	1.86	82.8	46.6	----	1.30	40.0
4	Manure+lime+rock phosphate	66.5	49.6	2.29	84.3	46.8	----	1.48	48.0
5	Manure+lime+acid phosphate	59.7	50.8	2.56	78.0	44.4	----	1.30	40.5
6	Manure+lime+complete commercial fertilizer	64.2	43.4	2.50	79.1	47.4	----	1.39	41.0
7	Check	57.1	47.6	1.51	62.9	33.5	----	0.95	36.8
8	Crop residues	56.9	47.6	1.17	61.7	36.2	----	0.78	37.8
9	Crop residues+lime	53.1	58.9	1.27	63.4	35.6	----	1.13	50.6
10	Crop residues+lime+rock phosphate	61.4	63.7	2.31	60.6	34.9	----	1.15	44.8
11	Crop residues+lime+acid phosphate	62.9	70.6	2.34	59.1	38.1	----	1.41	44.2
12	Crop residues+lime+complete commercial fertilizer	60.0	50.2	2.25	74.7	44.9	----	1.35	44.2
13	Check	----	55.6	1.35	64.8	40.0	----	0.43	41.0

1. Plot 13 cut by mistake.
2. Wet spring reduced crop on manured plots; 4 tons lime, September.
3. Poor drainage made series weedy in spots.
4. No results taken.
5. Carried as residual series. No applications made since spring of 1923.
6. Field damaged by hot winds and dry weather.

The results secured on the Carrington silt loam on the Springville Field, series II, in Linn County are given in table XX. Here again the beneficial effect of the manure is evidenced by the increased crop yields secured every season. In some instances, as on the corn in 1922, there was a very large gain in the crop growth. Lime with the manure showed a beneficial effect on the crops grown in practically every case. The clover in 1921 showed the most pronounced increase. Rock phosphate with the manure and lime increased the crop yields in every season but in some cases the increases were very small. The clover in 1921 was benefited to the largest extent. The acid phosphate with the manure and lime showed a greater effect than the rock phosphate in some cases but in general the influence was less evidenced except on the clover in 1921. The complete commercial fertilizer showed no better effect than the rock phosphate and the acid phosphate except in the case of the clover in 1921 where it gave a larger increase than did the rock phosphate.

The crop residues showed slight gains on the crops secured in some seasons. Lime with the crop residues brought about definite increases in crop yields in several cases, the largest influence being noted on the corn in 1926. The rock phosphate with the crop residues and lime increased crop yields in practically all seasons, showing up particularly well on the clover in 1921. The acid phosphate gave increases in all seasons, having a somewhat greater effect in some years, particularly on the clover in 1925. In other cases the differences were small. The complete commercial fertilizer had a greater effect on the corn in 1922 and in 1923 than did the acid phosphate but in other cases it showed less value.

From the results secured on these two series on the Springville field it would seem evident that the application of manure is particularly valuable on the Carrington silt loam and liberal applications of this material should be made. The type is acid in reaction and the use of lime is very desirable. Applications of a phosphate fertilizer are to be recommended. Whether acid phosphate or rock phosphate should be employed cannot be definitely stated at the present time.

THE WAVERLY FIELD

The data secured from the field experiment on the Carrington loam on the Waverly Field No. 2, series I in Bremer County are given in table XXI. The beneficial effect of manure on this soil is evidenced by the increased crop yields secured in practically every season. In some cases very large gains were noted, as, for example, on the clover in 1919. Lime with the manure brought about increased crop yields in practically all seasons. The effect was particularly evidenced on the oats in 1921, and on the same crop in 1925. The yield on plot 3 in 1919 was evidently abnormal. Rock phosphate with the manure and lime increased the crop yields to a very pronounced extent in some seasons but in one or two seasons showed no beneficial effect. The clover in 1919 was increased to the largest extent, but there was a large influence also on the oats in 1925. The acid phosphate showed a greater effect than the rock phosphate in most seasons. The differences, in general, however, were not very large. In one case the acid phosphate showed less effect than the rock. The complete

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

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

1. Six tons lime, fall 1917.
2. Soybeans planted in corn, both crops poor. Wet spring injured plots in center series. Plots 5 and 6 and crop residue plots weedy.
3. Plot 3 too high, many morning glory vines on plot.
4. Stand uneven on 2 and 4.
5. No crop data secured owing to drought.
6. Crop badly damaged by frost.
7. Barley seeded by mistake on plot 1.
8. Pastured.

commercial fertilizer had a greater effect than the acid phosphate in one or two cases, but in general showed a very similar influence to that brought about by the acid phosphate. A very large increase was noted, however, in 1925 from the complete fertilizer.

The crop residues showed very little effect on the various crops grown. Lime with the residues increased the crop yields in all seasons. In some cases very large gains were noted, particularly on the clover in 1919 and in 1922. Gains were also shown on the oats in 1921 and in 1925. The rock phosphate with the crop residues and lime increased the crop yields to a considerable extent in practically every case. The largest influence was noted on the clover crop and on the oats in 1925. The acid phosphate with the crop residues and lime had a larger effect than the rock phosphate in practically every season. In some cases the gains were very pronounced, as for example on the clover in 1919 and in 1922. In other cases the differences were not large. The complete commercial fertilizer with the crop residues and lime exerted very much the same influence as did the acid phosphate, showing slightly greater results in some cases and smaller in others.

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

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

1. Six tons lime, fall 1917. Heavy rains washed 11, 12 and 13 badly.
2. Plots 1 and 2 poorer in fertility than other plots.
3. Dry season.
4. Plot 13 high probably due to manure application made thru error.
5. Low yield on plot 12 due to part of crop lost in threshing.
6. Grasshoppers destroyed the crop on plot 1 and damaged west side of all plots.

The results secured on the Carrington loam on the Waverly Field No. 2 series II in Bremer County are given in table XXII. Here again the beneficial influence of manure on this soil is evidenced by the great increases in crop yields secured in practically every season. The clover in 1920 and 1921 and the corn in 1922 and 1923 showed the largest influence from the use of the manure. The application of lime with the manure brought about distinct gains in crop yields in every season. In some cases the gains were very large as, for example, on the clover in 1920, 1921, and 1925, on the corn in 1923, on the oats in 1924, and on the alfalfa in 1926. The rock phosphate with the manure and lime showed a beneficial effect on the crop yields in most seasons. The differences, however, were not very distinct, and in some cases no gains were noted. The acid phosphate with the manure and lime increased the yields to a considerable extent in most seasons, the largest effect being noted on the clover and alfalfa crops, altho there was a large effect also on the oats in 1924. The complete commercial fertilizer showed better results than the acid phosphate in some cases but in several instances did not bring about as large increases.

The crop residues showed little effect on crop yields, small increases being noted only in one or two cases. Lime with the residues increased the crop yields in a very pronounced way, in some cases bringing about enormous increases, as, for example, on the clover in 1925. The rock phosphate with the crop residues and lime increased the yields in most seasons, the differences being considerable in some cases, as for example on the clover crops and on the oats in 1924. The acid phosphate with the crop residues and lime showed better results than the rock phosphate in one or two cases, but the differences were not large and in general the two phosphates seemed to give about the same returns. The complete commercial fertilizer showed a larger effect than the acid phosphate in some cases, particularly on the clover and timothy in 1921. But in other cases there was a smaller influence from the complete fertilizer.

These results as a whole show that the Carrington loam will respond very profitably to applications of manure, lime and a phosphate fertilizer. Liberal additions of manure to this type are strongly to be recommended, and large crop increases will follow its application. The type is acid and the addition of lime is very necessary for the best growth of general farm crops and particularly for securing the most desirable yields of legumes. The use of a phosphate fertilizer seems to be particularly profitable on this type. Acid phosphate and rock phosphate both bring about large increases in the yields of general farm crops.

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

The laboratory, greenhouse and field experiments which have been discussed in previous pages form the basis for some general recommendations for the treatment of the land of the county as a whole and these will be summarized briefly. The indications secured from the various experiments which have been carried out, point rather definitely to the value of certain treatments for the soils of the county. The suggestions which are offered in the following pages are based not only upon the results of these experiments but also upon the practical experience of many farmers. Any of the recommendations which are made here can be put into effect on any farm.

It is very desirable to carry out tests on individual farms, especially to test the use of phosphate fertilizers, in order to determine whether rock phosphate or acid phosphate will be the more profitable for use. It should be emphasized that simple experiments may be carried out on any farm and data of considerable value to the individual farmer may be secured in this way. The results will also be of interest to other farmers who are located on the same soil type. Farmers are urged to carry out tests on their own soils and thus aid in solving the fertility problem for the particular soil type. The Soils Section of the Iowa Agricultural Experiment Station will aid and advise farmers who may be interested in conducting fertilizer tests on their own soils.

LIMING

The various soil types mapped in Benton County are all acid in reaction and it is apparent that there is a general need for lime on these soils. The figures in the tables given earlier in this report, showing the limestone requirements of the various types, should be considered merely indicative of the needs of the

various soils. There is a wide variation in the acidity or lime requirements of soils even when they are of the same type, and occasionally even when samples are secured from the same area. No average figures for lime requirements should, therefore, be considered satisfactory for use as a basis upon which to figure the addition of lime to soils. Samples from each individual field should always be tested before lime is applied. In this way the amount of lime necessary to remedy the acidity may be added in every case.

The only conclusion which can be drawn from the analyses given, is that the soils of the county are all highly acid in reaction. Tests should be carried out, therefore, on all these soils and the amount of lime, shown to be necessary by the tests, should be applied if crop growth is to be satisfactory. Farmers may test their own soils for lime requirements but they will usually find it more satisfactory to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. In this way, they may be assured that they will be applying the proper amount of lime to the particular area.

The best growth of general farm crops and particularly of such crops as clover and alfalfa, requires the neutralization of acid conditions in the soils by the application of lime. Large increases in crop yields are frequently secured from the application of lime to acid soils. The greenhouse and field tests which have been described earlier in this report have shown very beneficial effects on crop yields from the application of lime. Not only are the legume crops largely benefited, but there are frequently considerable increases in the yields of other general farm crops. Farm experience in this county has likewise amply demonstrated the value of applying lime to the soils when they are acid. One addition of lime will not be sufficient for all time and hence tests of the soil for lime needs must be made at regular intervals if the reaction is to be kept satisfactory. It is recommended that soils be tested once in a four year rotation and that lime be applied, as needed, preceding the growing of the legume crop of the rotation.

Further information regarding the use of lime on soils, losses by leaching and other factors connected with liming, are given in Extension Bulletin No. 105 of the Agricultural Extension Service, Iowa State College. Here also will be found a list of companies prepared to furnish limestone for agricultural use in the state.

MANURING

In some cases the supply of organic matter in the soils of Benton County is rather low, while in other instances it seems quite adequate. On the average, it appears that there is no large deficiency in organic matter in the soils of the county in general. In some cases, however, there is need for the application of organic matter at the present time in order to put the soils in a better condition for crop growth. And in all cases, the use of organic matter at regular intervals on the soils of the county is necessary if the supply is to be kept up.

Farm manure is the best and the cheapest natural fertilizing material which can be employed on the farm. It plays a large part in keeping up the supply

of organic matter in the soil. The use of farm manure on the soils of Benton County will be attended with large crop increases, as has been evidenced by a number of experiments on the soils of the county and also by considerable farm experience. On those soils which are lighter in color and coarser in texture, the liberal use of farm manure is very desirable, but even on those types which are darker in color and apparently better supplied, the use of farm manure will bring about very profitable increases in crop yields. On the latter types, smaller applications of farm manure should be employed and the application should not be made immediately preceding the growing of the small grain crop of the rotation, since it may cause the crop to lodge. Applied at other points in the rotation, however, farm manure has proved very valuable. The experiments reported on some of the Carrington soils, the Tama silt loam and the Clinton and Grundy silt loams have indicated large returns from the application of manure. Large returns may also be expected on the other soil types on the uplands and on the various soils on the terraces and bottomlands in the county.

On farms on which sufficient manure is not produced to provide for all the lands at regular intervals and on grain farms where no manure is produced, the use of well-inoculated leguminous crops as green manures is strongly to be recommended. Green manuring is a very desirable practice as a supplement to the use of manure or as a substitute for that practice, and it may be used with considerable profit on many of the soils in Benton County.

In many cases the crop residues are burned on the farm or otherwise destroyed and when this is the case, there is a large loss of valuable fertilizing material. On the live stock farm, the residues should all be used for feed or bedding and returned to the land with the manure. On the grain farm, they may be applied directly or they may be stored and allowed to decompose before application.

THE USE OF COMMERCIAL FERTILIZERS

The analyses given earlier in this report have indicated that the supply of phosphorus in the soils of Benton County is generally quite low. It would seem, therefore, that the use of phosphorus fertilizers on these soils might be of considerable value, and it is certain that some phosphorus carriers will be needed in the very near future if indeed they do not prove of value at the present time. Tests which have been carried out in the greenhouse and in the field on some of the more extensive soil types, have indicated quite definitely, that a phosphorus fertilizer may often be applied to the soils of this county with profitable effects.

Some comparisons have been made of the value of rock phosphate and acid phosphate as a means of applying phosphorus to the soils of this county. In some seasons and with certain crops, acid phosphate has proved more profitable, but in other cases, rock phosphate has given quite as desirable results.

Definite conclusions regarding the relative value of the two phosphates have not yet been possible from the tests which have been carried out, and farmers are urged to determine the comparative effects of the two materials by tests carried out on their own farms. Simple experiments along this line may be

conducted quite readily and directions which may be followed in the carrying out of such tests, are given in Circular 97, of the Iowa Agricultural Experiment Station. It seems quite certain that the soils of the county will respond to applications of a phosphate fertilizer and it is particularly desirable, therefore, that the relative economic returns which may be secured from the two phosphates be determined under general farm conditions. By the carrying out of the tests suggested, farmers may determine the response of their own particular soils to phosphorus and learn which phosphate fertilizer may be employed with the largest profit under their particular conditions.

Most of the soil types in Benton County are fairly well supplied with nitrogen but in one or two cases there is an obvious deficiency. The Carrington sand, Clinton fine sandy loam, the O'Neill sandy loam, and the Sarpy sand are particularly low in nitrogen. The Lindley fine sandy loam, the Carrington fine sandy loam and other sandy types in the county are, likewise, rather poorly supplied with nitrogen. Nitrogen containing fertilizers will be particularly valuable on these soils but they would also bring about very large beneficial effect on some of the other types.

There are three natural nitrogenous fertilizing materials which may be used on the farm, and these are farm manure, crop residues and leguminous green manures. Farm manure is a very important nitrogenous fertilizer. It returns considerable amounts of the nitrogen which has been removed by the crops grown. When it can be applied to the land in liberal amounts, it aids considerably in keeping up the supply of nitrogen in the soil. The proper utilization of all the crop residues produced on the farm also aids materially in keeping up the supply of nitrogen. The best source of nitrogen, however, for increasing the nitrogen content of the land, is leguminous crops used as green manures. When well inoculated, these crops take a large part of their nitrogen from the atmosphere and when they are turned under in the soil there is a large increase in the nitrogen content. Green manuring is a very desirable practice as a means of increasing the nitrogen content of the soil.

Commercial nitrogenous fertilizers are probably unnecessary for general use on the soils of Benton County at the present time. The nitrogen supply may be more economically maintained by the proper use of leguminous green manures, farm manure and crop residues. Small amounts of nitrogenous fertilizers may occasionally be used with profit as top dressings, but for general farm crops their use cannot be recommended.

Earlier analyses of the soils of the state have indicated a large content of potassium and it is certain that there is a considerable supply of this element in the soils of Benton County. There is certainly enough potassium to supply the needs of crops for many years to come. All that is needed is to provide the necessary conditions in the soil so that this total potassium may be changed into an available form as rapidly as it is needed. The proper handling of the soil from the standpoint of drainage and cultivation, the use of lime, and the incorporation of farm manure and green manures, will aid materially in insuring the production of available potassium, rapidly enough to supply the needs of crops. Commercial potassium fertilizers cannot be recommended for general use at the present time in the county. Tests on a small scale should be carried out before there is any general use of a potassium fertilizer. Farmers who are interested may test the application of 50 to 100 pounds of muriate of potash along with acid phosphate in comparison with the acid phosphate alone, and thus determine whether the use of the potassium is profitable.

Complete commercial fertilizers have been tested in experiments carried out on some of the soils of the county and, in general, they have not proved as profitable for use as acid phosphate. Frequently they bring about as large or even larger crop increases but owing to their greater cost, the profits are usually smaller. As the soils are very well supplied with potassium and in many cases also with nitrogen, it would seem that the value of the complete commercial fertilizer is probably due mainly to its phosphorus content, hence it might be expected that acid phosphate would give quite as desirable crop increases and at a lower cost. Frequently also, rock phosphate proves as profitable for use as the complete fertilizer. In general it would appear, then, that the use of a phosphate fertilizer is to be recommended in preference to the application of a complete commercial fertilizer.

However, there is no objection to the addition of complete commercial fertilizers to the soil and if tests carried out on the farm in comparison with acid phosphate indicate a superior value for the complete fertilizer, taking into account the greater cost of the material, then the material may be used with the assurance of profit.

DRAINAGE

The natural drainage system of Benton County is fairly well developed as has been indicated in the drainage map given earlier in this report. Most of the upland areas are very well drained and only in the case of the Clyde silt loam is there any very definite need of drainage on the uplands. Occasionally there are areas in some of the other soil types where drainage would be desirable and the installation of tile would improve the conditions. For example, there are local areas in the Carrington silt loam, the Carrington loam and the Grundy silt loam on the uplands, where tiling would undoubtedly be of value. In several cases on the terraces and bottoms the soil types are poorly drained. The Bremer soils in particular show a lack of adequate drainage and the Chariton soils on the terraces are also rather poorly drained. The Wabash soils and the areas of peat on the bottomlands are generally in need of drainage.

Land which is too wet will not produce satisfactory crop yields and even if the area is only limited in extent, it is often very desirable to tile it out in order to improve the drainage conditions.

The first treatment which some of the soils need and which is required by individual areas in many of the types, is adequate drainage. Until this is accomplished, satisfactory crop yields will not be secured. Applications of fertilizing material will be of little or no value on soils which are too wet. While the tiling out of areas of land which are improperly drained may be somewhat expensive, the returns which are secured are distinctly profitable and it is a very desirable operation.

THE ROTATION OF CROPS

The continuous growing of any one crop very quickly reduces the fertility of the soil, and it is a definitely unprofitable practice. The growing of any one crop, even if it is a particularly valuable crop, such as corn, will not prove as profitable over a period of years as following a rotation which may contain other crops which are not as valuable. This is due to the fact that there is a very rapid decrease in production of a crop when it is grown continuously on land. Yields are reduced very rapidly and in spite of the larger value of the crop, the profit from the crops grown in a rotation over a period of years will be very much greater.

There is much definite experimental evidence in support of the desirability of adopting a proper rotation of crops for the securing and maintaining of the best fertility conditions in the soil. There is also much support for the conclusion that it is more profitable in the long run to rotate crops. Farmers should not be deluded by the higher value of some particular crop into believing that they can grow that crop continuously and secure greater profits from their land.

No special crop rotation experiments have been carried out in Benton County but there are numerous good rotations in use thruout the state, many of which may be suitable for use in this county. No one rotation can be recommended as most desirable for all conditions, and in fact it may be said that any rotation will be valuable provided it contains a legume crop and provides for the growing of a money crop in the rotation as frequently as feasible. From among the following rotations, some one way may be chosen which will be suitable for use under almost any conditions in this county.

1. SIX-YEAR ROTATION

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

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

2. FOUR OR FIVE-YEAR ROTATION

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

3. FOUR-YEAR ROTATION WITH ALFALFA

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

4. FOUR-YEAR ROTATIONS

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

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

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

5. THREE-YEAR ROTATIONS

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

First year —Corn.
Second year—Oats or wheat (with sweet clover.)
Third year —Sweet clover (The clover may be mixed clovers and used largely as pasture and green manure.)
(This may be changed to a two-year rotation by plowing the sweet clover under the following spring for corn.)

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

THE PREVENTION OF EROSION

Erosion is the carrying away of the surface soil thru the free movement of water over the surface of the land, known as sheet erosion or the washing away of the soil with the formation of gullies, gulches or ravines.

Erosion occurs to a considerable extent on some of the soil types in Benton County. The Lindley soils on the rolling to rough or broken areas of upland, the Clinton soils on the more rolling to rough areas of loessial upland, and in some areas of the other upland types, considerable erosion has occurred. The shallow phase of the Tama silt loam is a result of the washing away of considerable amounts of the surface soil. In many cases this surface washing has been very significant. Wherever gullying occurs in the uplands, it is very evident and there is more need for the protection of the land from the formation of gullies, but where surface washing occurs, the disastrous effects are not so evident and frequently the need of protecting the soil is not recognized.

Various methods are followed for the control and prevention of erosion in Iowa. These methods differ somewhat depending upon the type of erosion. Erosion occurring due to "dead furrows" may be controlled by "plowing in" by "staking in" or by the use of earth dams.

Small gullies may be filled by the "staking in" operation, by the use of straw dams, earth dams, Christopher or Dickey dams, Adams dams, stone dams, rubbish dams, woven wire dams, concrete dams. They may be prevented from occurring by thoro drainage or by the use of sod strips. Large gullies are similarly filled or prevented from occurring. Erosion in bottomlands is prevented by straightening the streams, by tiling and by planting trees up the drainage channels. Hillside erosion is controlled by the use of organic matter, by growing cover crops, by contour discing, by terracing, by deep plowing and by the use of sod strips.*

*See Bulletin 183. Soil Erosion in Iowa, Iowa Agricultural Experiment Station. Extension Service Bulletins 93, 94, 95, 96. Agricultural Extension Service, Iowa State College.

INDIVIDUAL SOIL TYPES IN BENTON COUNTY* **

There are 26 individual soil types in Benton County and these with the shallow phase of the Tama silt loam and the areas of meadow and peat, make a total of 29 individual soil areas. They are grouped into four groups; drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are eight drift soils in the county, classified in the Carrington, Clyde and Lindley series. Together they cover 26.0 per cent of the total area of the county.

CARRINGTON SILT LOAM (83)

The Carrington silt loam is the largest drift soil in the county and the second most extensively developed type. It occurs on 11.8 percent of the total area. It is most extensively developed in the southeastern part, occupying most of the upland between Shellsburg and the Iowa County line. It occurs extensively in Canton, Fremont and Lawrence Townships. In many sections of these townships it occupies the entire areas of upland. There are numerous small areas of the type in other parts of the county. Some of these are rather extensive in size. There is rather a considerable area extending from the central sections of Eden Township in the center of the county, into Big Grove Township. There is rather a large area on the western edge of the county in the southern part of Kane Township and in the northern part of Iowa Township. Another considerable area is found in the northern part of the county in Cedar Township, just west of Mt. Auburn. A number of other smaller areas of the type occur.

The surface soil of the Carrington silt loam, to a depth of about 10 inches, consists of a dark grayish-brown or dark brown mellow silt loam. Below this point there are a few inches of a dull brown silt loam, grading into a light brown or dull yellowish-brown compact silt loam to a depth of 18 to 30 inches. Below this point the subsoil is a light brown to yellowish-brown compact and moderately friable but ordinarily somewhat sticky, gritty, silty clay loam or clay loam. In places the lower subsoil shows some gray and brown mottlings and contains pebbles and gravel. Boulders are found thruout the soil section and occasionally on the surface. In topography the Carrington silt loam is gently rolling to rolling. Drainage of the type is good.

Practically all of the type is under cultivation and general farm crops are grown. Yields are very similar to those secured on the Tama silt loam, corn averaging from 40 to 50 bushels per acre, oats about the same, and hay from one to two tons per acre.

*Benton County adjoins Black Hawk County on the north and Linn County on the east. In some cases the soil maps of these counties do not agree along the boundaries. This is due to the fact that several types found in these adjoining counties on account of their very small areas have not been extended into Benton County. Usually the difference is only a slight change in texture. The Buckner silt loam of Linn County has been included with the Waukesha silt loam in Benton County and types of the Carrington, Buckner and Sarpy series have been included with other types of the same series in Benton County. The silty clay loams of the Clyde and Bremer series in Black Hawk County have been included with the silt loam of the same series in Benton County.

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

The Carrington silt loam is normally a rather productive type but crop yields may be considerably increased by proper methods of soil treatment. The beneficial effects of applications of manure, lime and phosphorus fertilizers have been shown in the experiments which have been reported in previous pages. The liberal application of manure to the soil is strongly to be recommended as large increases in crop yields are always secured from the use of this material. The type is acid in reaction and the addition of lime is very desirable in order to bring about the best growth of legumes and also to provide the best conditions for maximum yields of the other general farm crops. The use of a phosphate fertilizer is very desirable on the soil and large increases in crop yields are secured from the application of rock phosphate or acid phosphate. Which material should be employed cannot now be definitely stated. In many cases acid phosphate seems perferable but in other cases rock phosphate gives quite as large increases in crop yields. Tests of the two phosphates under individual farm conditions are very desirable.

CARRINGTON SANDY LOAM (3)

The Carrington sandy loam is the second largest drift soil in the county and the fifth largest individual soil type. It covers 5.2 per cent of the total area. Practically all of the type is found in the northeastern part, north and east of the Cedar River, where it occupies extensive areas on the uplands. It is the predominating type on the east slope of Bear Creek and in much of Polk Township. There is a smaller area of the type along the river northeast of Mt. Auburn and several small areas are found in Benton Township, southeast of Benton City.

The surface soil of the Carrington sandy loam consists of a dark brown or dull brown sandy loam or heavy sandy loam, extending to a depth of 18 to 20 inches. In some areas the soil is almost a loam in texture. Below 18 inches, there is a layer of a lighter brown compact sandy loam, which grades at about 24 to 30 inches into a light brown loamy medium sand or light sandy loam subsoil. Variations in the soil occur in different locations. In lower-lying areas, the surface soil is somewhat heavier in texture and darker in color, while in the higher portions the type is coarser in texture and browner or lighter in color, approaching the Carrington sand.

In topography the Carrington sandy loam is rolling and naturally well drained. It is not droughty which might be expected because of its sandy texture.

The type is utilized for the production of ordinary farm crops, corn, oats, barley, wheat, rye and clover and timothy being most commonly grown. In some areas, watermelons, cantaloupes and other truck crops are produced. Yields of the general farm crops and of truck crops are usually quite satisfactory. Large increases will be secured, however, by certain methods of soil treatment. The type is low in organic matter and will respond readily to applications of farm manure. The use of leguminous crops as green manures will also be very valuable on this soil. It is particularly important to build up the organic matter content of the soil in order to make it more productive. The type is

acid in reaction and will respond to the application of lime. Phosphate fertilizers will bring about crop increases on this soil. Acid phosphate will undoubtedly be very desirable for use in connection with the growing of general farm crops. Owing to the normal lack of organic matter probably acid phosphate will give better returns than rock phosphate on this soil. Complete commercial fertilizers may be used with profit where truck crops are grown and perhaps also in some cases where general farm crops are produced. Tests of the value of acid phosphate and complete commercial fertilizers on this soil are to be recommended.

CARRINGTON LOAM (1)

The Carrington loam is the third most extensive drift soil and the sixth largest type. It covers 4.4 per cent of the total area. It occurs most extensively north of the Cedar River in a belt one to two miles in width on each side of Prairie Creek and extending southeasterly thru Urbana. Numerous other areas of the type occur in various parts of the county. There is a rather considerable area on the western side of Pratt Creek in Cedar and Jackson Townships. A large body of this type is also found northeast of Mt. Auburn in Cedar Township and a smaller one directly north of Mt. Auburn. Small areas occur along some of the streams in the central part of the county, and several are found along Prairie Creek and Pine Creek in the southern part.

The surface soil of the Carrington loam is a dark brown to nearly black friable loam, extending to a depth of 12 to 16 inches. Below this point the subsoil is a somewhat lighter brown heavy loam at 22 to 24 inches becoming a light brown sticky fine sandy loam or sandy clay loam. Boulders are occasionally found on the surface of the soil and thru the soil section. In places there is a gradual graduation from Carrington loam into the Carrington silt loam and the boundary lines have been located rather arbitrarily.

In topography the Carrington loam is gently rolling to rolling. Drainage is generally adequate. In a few areas where the topography is more level the subsoil is not well drained and the type needs tiling. On the slopes more or less erosion has occurred and in some places the lighter colored subsurface and subsoil materials are exposed.

Most of the type is in cultivation and general farm crops including corn, oats, hay and barley are grown. Average yields of these are ordinarily quite satisfactory. The soil will respond readily, however, to applications of manure, lime and a phosphate fertilizer. The experiments discussed earlier in this report have indicated the large increases in crop yields which may be secured on this soil from the application of farm manure. The type is acid in reaction and for the best growth of legumes, lime should be applied. In many cases large increases in the yields of other crops are secured from this material. The use of a phosphate fertilizer has been attended in many cases with very profitable crop increases. Acid phosphate and rock phosphate have both been used to advantage on this soil. In some cases one material seems preferable while in other cases the other material gives quite as good results. Tests of both phosphates on this soil type are recommended.

CLYDE SILT LOAM (84)

The Clyde silt loam is the fourth largest soil type and the eighth in extent. It covers 2.8 percent of the total area. It occurs in numerous drainageways and in poorly drained, depressed areas in the uplands. Small areas of the type are found in all parts of the county. There are no large individual areas of the soil.

The surface of the Clyde silt loam is a black silt loam, extending to a depth of 8 to 12 inches, usually containing some gritty or fine sandy material. The subsoil is a sticky, silty clay loam, nearly black in color, changing at 20 to 24 inches into a dark gray plastic sandy clay, becoming more sandy and often stony near the 36 inch depth. The lower subsoil is usually more or less mottled and stained with rusty brown, yellowish-brown and light gray.

There are many variations from the typical soil. Where it occurs adjacent to sandy types there are areas where the surface soil is a more or less dark colored mucky sandy silt loam and the subsoil a grayish sticky sand or sandy clay. When found near loams or silt loams, the surface soil approaches a silty clay loam and the subsoil is more uniformly heavy in texture. In some areas the surface soil is almost a silty clay. In topography the Clyde silt loam is flat to depressed and the natural drainage is poor. In many seasons water remains on the areas for considerable periods. In some places the surface is boggy and somewhat hummocky.

The type is particularly in need of drainage in order to be made productive. Most of the undrained areas are used for wild hay and for pasture, and good stands of blue grass are maintained. Hay yields are good on the soil and when well drained satisfactory yields of corn may be secured. The type is not so well suited to small grains. If the areas are to be cultivated they should first of all be thoroly drained. Small applications of farm manure would be valuable on the drained areas to stimulate the production of available plant food. This material should not be applied preceding the growing of the small grain crop, since it may cause the crop to lodge. Small amounts applied at other places in the rotation will be of value. The type is acid and will respond to liming. The use of a phosphate fertilizer is very desirable. Tests of rock phosphate and acid phosphate are recommended.

LINDLEY SILT LOAM (32)

The Lindley silt loam is a minor type, covering only 0.7 percent of the total area. It occurs practically entirely in the southern part in Iowa and Leroy Townships, being found on the slopes and along the smaller streams and intermittent drainageways. There is one small tract in sections 4 and 9 of Harrison Township.

The surface soil of the Lindley silt loam is a light brown compact silt loam, 6 to 8 inches in depth. The subsoil is yellowish-brown or light brown, compact, plastic silty clay loam or clay loam, becoming somewhat lighter in color and more plastic at the lower depths. At 18 to 20 inches the subsoil is a gritty, sticky, dense dull yellowish clay, becoming mottled with brown and rusty

brown at the lower depths. The subsoil usually contains some sand, gravel and rock fragments.

The Lindley silt loam is rough to broken in topography. The surface drainage is good but the type is subject to very serious erosion.

About one-half of the total area of the type is in cultivation, the remainder being in pasture and forest. On the rougher areas, it would be undesirable in general to attempt cultivation, and much more satisfactory to allow the land to remain in pasture. On the smoother sections general farm crops may be grown. In these areas increased crop yields may be secured by the proper use of farm manure, lime and a phosphate fertilizer. The liberal application of manure is very desirable as the type is low in organic matter. Large increases in crop yields will result from the use of manure. The type is acid and will respond to applications of lime, especially for the best growth of legumes.

The application of a phosphate fertilizer is strongly recommended. Probably acid phosphate would be preferable for use because of the low organic matter content of the soil. However, tests of rock phosphate and acid phosphate may be carried out on this type to determine which material will be more profitable for use under individual farm conditions. It is very important when the type is cultivated that all precautions be taken to prevent the occurrence of erosion, as washing away of the surface soil and the formation of gullies may frequently occur.

CARRINGTON SAND (119)

The Carrington sand is a minor type, covering only 0.4 percent of the total area. It occurs mainly in association with the Carrington sandy loam north of the Cedar River, the largest areas being found just north of Vinton and in sections 15 and 16 of Harrison Township. Another considerable area is found in the vicinity of Benton City. A smaller body of the type occurs northwest of Mt. Auburn along the Black Hawk County line.

The surface soil of the Carrington sand is a grayish-brown or dark grayish-brown loamy medium textured sand, extending to a depth of 10 to 14 inches. The subsoil is generally a light brown or yellowish-brown incoherent, medium textured sand.

In topography the Carrington sand is undulating or dunelike. It is found on ridges and elevations above the adjacent sandy loam. Drainage is excessive and most of the type is droughty. When not protected by tree growth or other vegetation the soil is subject to wind action and considerable drifting occurs.

Most of the areas of the type in more exposed positions are uncultivated, but are used as pasture, altho their value for this purpose is low. There are some scattered trees on it, mostly small oak. The yields of general farm crops are usually unsatisfactory except in seasons of abundant rainfall. Some watermelons, cantaloupes and early truck crops are grown on the type.

If the Carrington sand is to be used for cultivated crops it needs first of all to be liberally supplied with organic matter. Large amounts of farm manure would be valuable and the turning under of leguminous crops as green manures would have a very beneficial effect. The type is acid and will

respond to liming. The use of phosphate fertilizers would undoubtedly be of value and tests of acid phosphate are recommended. Where truck crops are grown complete commercial fertilizers would undoubtedly be profitable. Experiences with other similar sandy soils indicates the possibility of reclaiming areas of this type by the proper utilization of green manuring materials and that satisfactory yields of general farm crops may then be secured.

LINDLEY FINE SANDY LOAM (136)

The Lindley fine sandy loam is a minor type, covering only 0.4 percent of the total area. Nearly all of it is found south of the Cedar River in Benton Township. There is one rather extensive area in sections 13, 14, 15, 23 and 24 of Benton Township. A rather considerable area is also found in sections 1 and 2 of Canton Township.

The surface soil of the Lindley fine sandy loam is a mellow fine sandy loam light brown in color and extending to a depth of 10 to 16 inches. The subsoil is a compact light brown fine sandy clay loam. In some areas it is a yellowish-brown somewhat sticky loamy fine sand below 28 to 30 inches while in other cases it consists of a compact, rather sticky, fine sandy loam, light brown to yellowish in color. Occasionally coarser sand and pebbles occur thru the soil section. There is much variation in the subsoil character.

In topography, the Lindley fine sandy loam is rolling to hilly, being confined in places to the ridges and slopes. The natural drainage is good. Only a small part of the type is under cultivation and a large proportion is kept in pasture and in forest, for which it is undoubtedly best fitted. On the cultivated areas, crop yields are not very satisfactory until the soil has been properly treated. It is in need of liberal applications of farm manure or the turning under of leguminous crops as green manures, in order to build up the supply of organic matter, in which it is particularly deficient. It is acid in reaction and will respond to liming. The application of a phosphate fertilizer would undoubtedly be desirable for general farm crops and tests of acid phosphate are recommended.

CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor type, covering only 0.3 percent of the total area. It occurs in a number of small areas mostly north of the Cedar River in association with the Carrington sandy loam and the Carrington loam. There is no large development of the type. The most extensive area is found southeast of Urbana, extending to the county line. There are several small areas of the type in other parts, occurring on knolls or knobs in the Tama silt loam upland.

The surface soil of the Carrington fine sandy loam is a dark grayish-brown or dark brown loose friable sandy loam, extending to a depth of 10 to 16 inches. Below this point, there is a lighter brown fine sandy loam, 6 to 8 inches in depth, grading into a yellowish-brown or light brown compact friable fine sandy loam. At 28 to 30 inches, the subsoil becomes somewhat lighter in color and texture, approaching a yellowish-brown loamy fine sand. In some areas the type resembles the Clinton fine sandy loam, especially where it occurs in the loessial uplands.

Most of the type is under cultivation and general farm crops are grown. There are a few forested areas where there is a growth of oak, hickory, and other trees. The type is thoroly and frequently excessively drained.

Yields of general farm crops on this soil may be increased greatly by the liberal application of farm manure, or the turning under of leguminous crops as green manures, in order to supply the deficiency in organic matter content. The type is acid in reaction and will respond to the application of lime, especially for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly be valuable on this soil and tests of acid phosphate are recommended.

LOESS SOILS

There are four loess types in the county classified in the Tama, Clinton and Grundy series, and these with the shallow phase Tama silt loam make a total of five loessial soil areas. Together they cover 56.8 percent of the total area of the county.

TAMA SILT LOAM (120)

The Tama silt loam is by far the largest individual soil type. Together with the shallow phase which is very limited in extent, it covers almost one-half of the total area, or 48.4 percent. It is the chief upland type in the county south and west of the Cedar River. It is very extensively developed particularly in the central and western townships. Large individual areas of the type are found on the uplands, cut by the areas of the Wabash and other bottomland soils along the stream courses and intermittent drainageways and by areas of the upland soils of the Carrington and Clinton series.

The surface soil of the Tama silt loam is a dark brown friable silt loam, 12 to 18 inches in depth. When moist, the surface soil is nearly black; when dry, it is a dark grayish-brown. There is a gradual change from this surface layer to the subsoil which consists of a light brown compact but friable silt loam or silty clay loam. In the lower part of the three-foot section, the subsoil is usually somewhat lighter in color and less friable in texture. In places where the soil is found in depressions, the lower subsoil shows mottlings of brown and yellow. It is somewhat dense and plastic.

The Tama silt loam has an undulating to gently rolling topography in practically all areas. South and southeast of Newhall the type occurs on low hills and here the topography is rather hilly to rolling. Natural drainage conditions in the soil are adequate. Erosion occurs to a slight extent on some of the more rolling to hilly areas. In general, however, the type is not seriously injured by the washing of water.

Practically all of the soil is under cultivation, general farm crops being grown. Corn yields 40 to 50 bushels per acre, hay yields from 1 to 2 tons per acre. Other crops grown include oats, some wheat and barley. A few of the more rolling areas and especially the narrow strips along the streams are kept in permanent pasture, along with the bottomlands.

The Tama silt loam is normally a rather productive type, but very considerable increases in crop yields are secured by the adoption of better methods

of soil treatment. The application of farm manure has been found to be specially valuable on this soil, and liberal applications are recommended for use. The experiments discussed earlier in this report have indicated the large crop increases which may be secured from the use of farm manure. The type is acid in reaction and applications of lime bring about large crop increases, especially in the case of legumes. The use of a phosphate fertilizer is strongly recommended on this soil. Tests of acid phosphate and rock phosphate have indicated desirable effects from both materials. Which one should be chosen for any particular condition must be determined for that condition. Tests of the two phosphates on individual farms are recommended.

TAMA SILT LOAM (SHALLOW PHASE) (143)

The shallow phase of the Tama silt loam is very minor in extent, covering considerably less than one percent of the total area. There are a number of small areas of the phase in the county, the largest being found in sections 7, 8 and 18 of Cedar Township. There are a few small areas along the bluffs of the Cedar River.

The surface soil of the shallow phase Tama silt loam consists of about 10 to 12 inches of a dark brown mellow silt loam. This is underlaid by a lighter brown, somewhat more compact, silt loam which, at 22 inches, changes to a coarse loamy sand, containing some fine gravel. At about 28 to 30 inches this rests on limestone. The depth at which this limestone occurs varies considerably in different places. In topography the phase is rolling in the larger areas and steep to broken in the smaller areas.

The phase occurs mostly on the bluffs and steeper areas along the rivers where the surface soil has been largely removed and the underlying rock material is closer to the surface. Little of it is cultivated, most of the areas being utilized for pasture and wood lots, which is certainly the best use for it. When cultivated the phase will respond to the same treatments as those recommended for the typical Tama silt loam. Liberal applications of farm manure should be made, the type is acid and should be limed and the application of a phosphate fertilizer would be very desirable.

CLINTON SILT LOAM (80)

The Clinton silt loam is the second largest loess soil, and the fourth most extensive individual type. It covers 7.1 percent of the total area. It occurs in numerous extensive areas in the county. The largest occurrence of the type is south of the Cedar River in Benton Township, and extending over into Canton Township. In fact, the type covers a very large part of Benton Township south of the river. The other most extensive area of the type is found in the southern part of the county, extending from Belle Plaine east along the county line. This area of the type is cut by the bottomland soils along the various streams and intermittent drainageways and by the areas of Lindley silt loam occurring on the rough uplands bordering these bottomland areas. There are a number of other rather extensive developments of the type notably in the central part of Big Grove Township, two areas in Jackson Township, just west of Garrison and two miles north of Garrison and in the northeast

corner of the same township adjacent to the river. There are several areas of the type likewise in the western and northeastern townships, occurring in association with the Tama silt loam on the uplands and the Clinton fine sandy loam on the uplands in the western areas. East of the Cedar River it is associated with the Carrington silt loam, the Carrington sandy loam and the Carrington loam on the uplands.

The surface soil of the Clinton silt loam is a light grayish-brown or dull gray slightly compact silt loam, 8 to 10 inches in depth. Below this point, the material becomes lighter in color, more compact and somewhat less friable. At about 18 to 20 inches the subsoil is a light brown to buff and at 30 inches the texture approximates a silty loam. In the areas which are better drained there is little or no mottling or staining in the subsoil but in the flatter areas the lower subsoil is mottled with yellow and brown and with a black to rusty brown color. Where the type occurs in association with the Clinton fine sandy loam, particularly in Harrison and Taylor Townships, there is a sandy variation usually approximating a very fine sandy loam at the surface and containing a considerable amount of fine and very fine sand in the subsoil.

In topography the Clinton silt loam is rolling to hilly or rough. In some places erosion has occurred to a considerable extent and the surface of the type is somewhat broken into gullies and ravines. Drainage is well established except for occasional small level areas.

About two-thirds of the type is in cultivation and utilized for the production of general farm crops. In the rougher areas the soil is used for pasture purposes and is mainly in forest. Corn is the leading crop grown on the cultivated portions with oats, wheat, barley and timothy and clover of minor significance.

Crop yields on the Clinton silt loam are in general smaller than those secured on the darker colored upland soils. The type will respond readily to applications of farm manure as it is rather low in organic matter. Experiments reported earlier have indicated the large increases in crop yields which may be secured from the use of farm manure. Where farm manure is not available for application the turning under of leguminous crops as green manures would serve to build up the supply of organic matter in the soil. The type is acid in reaction and will respond to applications of lime for the best growth of legumes. This material will also bring about large increases in the yields of other general farm crops. The application of a phosphate fertilizer would be very desirable on this soil. Whether rock phosphate or acid phosphate should be employed cannot be definitely stated. It would seem that in general the use of acid phosphate would probably be preferable because of the low organic matter supply in the soil. Tests of acid phosphate are particularly recommended on this type.

CLINTON FINE SANDY LOAM (122)

The Clinton fine sandy loam is a minor type, covering only 0.9 percent of the total area.

The type is practically all developed along the Cedar River, the most extensive area being found in Taylor and Benton Townships, extending in a belt

of varying width from northeast of Vinton north of the Cedar River to the county line. A second considerable area is found south of the Cedar River in Benton Township. Several small areas of the type have been mapped along the river and one of considerable size is found on the Black Hawk County line north of Mt. Auburn.

The surface soil of the Clinton fine sandy loam is a light brown loamy fine sand, extending to a depth of 18 to 20 inches. Below that point it becomes more loamy until at 28 inches the subsoil is a lighter brown compact rather heavy fine sandy loam. In some areas where the soil is in a virgin condition, and forested or in permanent pasture, there is a surface layer of 2 or 3 inches of dark colored material. In some places where the high-lying areas have been cleared the surface soil is a light brown loamy fine sand and there is little difference in color or texture to a depth of three feet. In depressions the soil is darker than typical, the subsoil heavier and more loamy. In areas where the type is associated with the Lindley fine sandy loam and the Carrington fine sandy loam there is a very gradual transition from one soil type to the other and the establishment of boundary lines is made rather arbitrarily. In topography the type is somewhat rolling to hilly. Drainage is naturally well established.

All of the type was originally in forest and part of it still supports a forest growth. On the cleared land general farm crops are grown but the yields are apt to be rather unsatisfactory particularly in seasons of dry weather. On the average yields are somewhat lower than those secured on the darker colored upland types.

This soil will respond readily to applications of farm manure and liberal amounts of this material should be applied. The turning under of leguminous crops as green manures would be a material help in building up the organic matter content of the soil. The practice of green manuring is very desirable as a substitute for the use of farm manure or as a supplement to that material. The type is acid in reaction and will respond to liming, especially for the best growth of legume crops. The use of a phosphate fertilizer is certainly to be recommended and tests of acid phosphate are very desirable. In some cases rock phosphate might prove equally profitable, hence both phosphates may be included in tests carried out on the soil. In general, however, the acid phosphate would probably be preferable for use because of the low organic matter content of the soil and hence the probable low availability of rock phosphate.

GRUNDY SILT LOAM (64)

The Grundy silt loam is a minor type, covering only 0.4 percent of the total area. Practically all of it is found in small areas in the western townships. The largest development of the type is in Monroe Township. There are no very large areas, the largest being found just northeast of Dysart.

The surface soil of the Grundy silt loam is a dark brown to nearly black silt loam, extending to a depth of 10 inches. Below this point there is a gradual change through a depth of 3 to 4 inches into a bluish-black or dark grayish-brown compact silt loam or silty clay loam, which at 20 inches becomes a

bluish-gray stiff, rather plastic silty clay, mottled with yellowish-brown and rusty brown. The material is lighter in color at the lower depths and at 30 inches becomes a yellowish-brown, dense plastic silty clay, mottled with rusty brown.

In topography the Grundy silt loam is level to gently undulating. It occurs on the flat upland areas in the more rolling Tama silt loam regions. Natural drainage of the type is poor owing to the level topography and the rather impervious character of the subsoil.

The type is used for the growing of general farm crops and yields are usually satisfactory especially if adequate drainage has been provided. Where the areas have not been well drained yields are somewhat lower than those secured on the Tama silt loam.

The first treatment that areas of this soil need is drainage. It will then respond to applications of farm manure as has been indicated by numerous field tests. The type is acid and will respond to applications of lime. The use of a phosphate fertilizer is recommended and tests of rock phosphate and acid phosphate should be carried out. In some cases one material seems preferable while in other cases the other gives quite as good results. The evidence from many experiments points definitely to the fact, however, that the soil will respond in a very large way to applications of some phosphorus carrier.

TERRACE SOILS

There are eight terrace soils in the county classified in the Waukesha, Bremer, Buckner, O'Neill, Chariton and Judson series. Together they cover 6.1 percent of the total area.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the largest individual terrace type and the seventh largest individual soil. It occurs on 2.9 percent of the total area. There is a considerable development of this type on the high terraces along the streams of the county particularly in the western part. The largest development is found in Cedar and Jackson Townships. There are numerous areas, however, in other parts of the county. The largest individual areas are along Rock Creek, northwest of Mt. Auburn, along Pratt Creek, southwest of Mt. Auburn, along Wolf Creek in the extreme northwestern part of the county, west and southeast of Vinton in the vicinity of Belle Plaine and along Wild Cat Creek, Bear Creek, Dry Creek and Mud Creek in the southeastern part of the county.

The surface soil of the Waukesha silt loam is a friable dark brown silt loam, 12 to 18 inches in depth. The subsoil is a light brown compact silt loam or silty clay loam to a depth of 36 inches. In many places, at 28 or 30 inches, the subsoil is looser, and may consist of a gritty loam or silt and loamy fine sand. The sandier subsoil is usually found near the streams. In the small areas along the Cedar River the type is really a loam. Here the soil consists of 12 to 16 inches of a dark brown or dark grayish-brown loam or gritty loam, underlaid by a compact friable light brown silty loam or gritty loam. These areas have not been separated as Waukesha loam because of their small extent.

The Waukesha silt loam is found on terraces at moderate elevations above the streams. Generally there is a distinct drop to the first bottoms, but occasionally the slope to the streams is gradual. In topography the type is nearly level to very slightly undulating. As a rule the drainage conditions are excellent.

The soil is all utilized for the production of corn and other general farm crops. Yields of corn average 50 to 60 bushels per acre. Small grain crops and timothy and clover give excellent yields. In general the type is about the same in productivity as the Tama and Carrington silt loams.

Increased yields may be secured on the soil by the application of farm manure, the use of lime and the addition of a phosphate fertilizer. While the type is not low in organic matter the use of farm manure has been found to be valuable in increasing crop yields. The soil is acid in reaction and the addition of lime would be desirable. The application of a phosphate fertilizer, either rock phosphate or acid phosphate would certainly prove profitable.

BREMER SILT LOAM (88)

The Bremer silt loam is the second largest terrace soil, covering 2.2 percent of the total area. It occurs in a number of small areas in various parts of the county. The most extensive development of the type is found, however, in the southern part on the low terraces along Prairie Creek. There is also considerable development in the central part of the county along Hinkle Creek and along the other tributaries of the Cedar River in that section. A rather considerable area is found along Pratt Creek in Cedar Township. There are several other areas of considerable size in Cedar Township. Probably the largest individual area of the type is found south of Mt. Auburn.

The surface soil of the Bremer silt loam is a dark brown to nearly black, mellow, silt loam, extending to a depth of 10 to 14 inches. Below this point there is a layer, several inches in depth, thru which the surface soil gradually merges into a dull grayish-brown or grayish-black compact, plastic, silty clay. Between 20 to 30 inches the subsoil is encountered. This consists of a lighter colored or dull yellowish-gray, dense silty clay, mottled with rusty brown.

The type is found on low second bottomlands along the streams. Some of the lower-lying areas are only slightly higher than the adjacent areas of the Wabash silt loam on the bottoms. In topography the soil is nearly level to slightly sloping and drainage is naturally inadequate, both because of the topographic position and because of the impervious character of the subsoil. In some areas open ditches and tile drains have brought about considerable improvement in the drainage of the soil.

The type is practically all under cultivation altho in a few cases it is utilized for pasture. When it is well drained excellent yields of general farm crops are secured. Corn and hay do particularly well on this soil. Small grains produce well but have a tendency to lodge.

This soil needs drainage first of all to make it more productive. When this is accomplished, very good yields are ordinarily secured. The application of a small amount of farm manure would be valuable on newly drained areas of the type. Manure should not be applied, however, just preceding the growing

of the small grain crop since it may cause the crop to lodge. Small amounts at other points in the rotation will, however, prove of value. The type is acid and will respond to applications of lime if the best growth of legumes is to be secured. The addition of a phosphate fertilizer would undoubtedly prove profitable on this soil. Whether rock phosphate or acid phosphate should be employed cannot definitely be stated.

BUCKNER SANDY LOAM (40)

The Buckner sandy loam is a minor terrace type in the county, covering only 0.3 percent of the total area. It occurs in a few small scattered areas along the Cedar River, on the low second bottoms, just above overflow. The largest individual areas of the type are just north of the river on the Linn County line and in sections 28 and 29 of Harrison Township.

The surface soil of the Buckner sandy loam is a dark brown loose sandy loam, extending to a depth of 12 to 14 inches. Below this point, there is a gradual change into the subsoil, consisting of a lighter brown or brown loose sandy loam. At 30 inches the subsoil becomes a light yellowish-brown slightly loamy sand. In topography the soil is smooth to nearly level, drainage is good and in places excessive.

Practically all of the soil is under cultivation, general farm crops being grown. In seasons of average rainfall the yields are fairly satisfactory. It will respond readily, however, to applications of farm manure for the production of better yields of general farm crops. Where farm manure is not available in sufficient quantities to supply the needs of the soil, the turning under of leguminous crops as green manures would be very desirable. Both farm manuring and green manuring are most important practices to be followed in building up the organic matter content of this soil and making it more productive. The type is acid in reaction and will respond to liming. The use of a phosphate fertilizer is very desirable. Probably acid phosphate would be of more value at the present time than rock phosphate owing to the low content of organic matter in the soil.

O'NEILL LOAM (108)

The O'Neill loam is a minor type of soil, covering only 0.2 percent of the total area. Practically all of the type is found north of the Cedar River in areas which are rarely more than a fourth of a square mile in extent. Most of the areas are found in Taylor and Harrison Townships. One or two small areas of the type occur in other parts of the county.

The surface soil of the O'Neill loam is a dark brown friable loam or gritty silty loam, extending to a depth of about 12 inches. Below this point there is a brown or light brown compact loam. At 24 inches the texture becomes lighter and at about 30 inches the subsoil is a mixture of light brown sand and gravel. On the areas adjoining the first bottoms or streams the gravelly subsoil is more open and loose than in the areas nearer the upland.

The O'Neill loam occurs on narrow strips of terraces 10 to 20 feet above the first bottoms. In topography the soil is nearly level. Drainage is well established and in most cases the loose porous subsoil causes the soil to be droughty.

Practically all of the O'Neill loam is used for cultivated crops or for pasturage. In seasons of normal rainfall good yields of corn, small grains and hay crops are secured. The type will respond, however, very definitely to applications of farm manure. Liberal amounts of this material should be applied. The turning under of leguminous crops as green manures would undoubtedly prove valuable in many cases as a supplementary treatment to the use of farm manure. The type is acid and will respond to liming for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly prove of value.

O'NEILL SANDY LOAM (126)

The O'Neill sandy loam is a minor type of soil, covering only 0.2 percent of the total area. It occurs in a number of small areas on the low second bottoms along the Cedar River. The largest development of the type is found north of Vinton in Taylor and Harrison Townships. There are also several areas along Big Wolf Creek in the northwestern part of the county.

The surface soil of the O'Neill sandy loam is a brown to dark brown sandy loam, extending to a depth of 12 to 16 inches. The subsoil is somewhat lighter in color and less loamy in texture and at about 24 to 28 inches it becomes a yellowish-brown loose incoherent sand, medium in texture. In some places it contains considerable amounts of gravel. In the areas along Big Creek near Shellsburg, the surface soil is a fine sandy loam but because of the small extent of these areas they have been included with the sandy loam.

In topography the O'Neill sandy loam is generally smooth or slightly sloping, becoming somewhat undulating in places. Drainage is good and in most places excessive. Crops are apt to suffer from drought in dry seasons.

General farm crops are grown including corn, oats, rye, and forage crops. Some truck crops, principally melons are produced near Vinton. A portion of the soil is used for pasture.

This type will respond to applications of farm manure and liberal amounts of this material should be added. Leguminous crops used as green manures would improve the fertility conditions in the soil considerably and green manuring will often be a very desirable practice as a supplement to the use of farm manure. The building up of the organic matter content of the soil is particularly important and this may be accomplished by the use of farm manure or green manures. The type is acid and will respond to lime for the best growth of legumes. The application of a phosphate fertilizer would undoubtedly be desirable and tests of acid phosphate are recommended.

CHARITON SILT LOAM (105)

The Chariton silt loam is a minor type of soil, covering only 0.1 percent of the total area of the county. It is found in a few small scattered areas, the most important occurring in section 16 of Bruce Township, about three miles northwest of Mt. Auburn, and just west of Vinton.

The surface soil of the Chariton silt loam is a dark brown or grayish-brown moderately friable silt loam, extending to a depth of about 6 inches. The subsoil is a grayish or ashy gray rather mealy silt loam, slightly mottled or stained with yellow and yellowish-brown. At about 24 to 28 inches the soil

is a whitish grayish-brown compact, rather plastic, silty clay loam or silty clay, mottled with yellowish-brown.

In topography the Chariton silt loam is level, being found on the high terraces associated with the Waukesha and Bremer soils. The drainage of the type is adequate in some places but in the main is rather deficient.

Most of the type is utilized for pasture. There is a scattering forest growth consisting mainly of oak. Good bluegrass pastures are maintained. Where there is no drainage yields of cultivated crops are apt to be unsatisfactory. When well drained, however, corn and other general farm crops will yield very well.

The first treatment needed to make this soil productive is adequate drainage. The installation of tile is very desirable. Applications of farm manure would then be valuable in increasing crop yields on the type. It is acid in reaction and the use of lime is very desirable for the best growth of legumes. A phosphate fertilizer would undoubtedly prove of value and tests of rock phosphate and acid phosphate are recommended.

BREMER SILTY CLAY LOAM (43)

The Bremer silty clay loam is a minor type, covering only 0.1 percent of the total area. It is found mainly in three areas the largest of which occurs on the south side of Prairie Creek on the Linn County line.

The surface soil of the Bremer silty clay loam is a black friable silty clay loam, extending to a depth of 8 inches. The subsoil is a nearly black compact silty clay loam or clay loam, gradually taking on a very dark gray color, faintly mottled in most areas with brown or rusty brown. At 24 to 28 inches, the subsoil is a dark gray plastic silty clay, mottled with light brown, gray or bluish-gray.

The Bremer silty clay loam occurs on the low second bottoms and the topography is nearly level. There are a few depressions in the type. It is above overflow. The drainage of the soil is naturally poor owing to the level topography and heavy subsoil.

A portion of the soil is utilized for pasture purposes but most of it is under cultivation, corn being the principal crop grown. Yields are very much the same as on the Bremer silt loam.

The first treatment needed for this type is the installation of tile drains. When this is accomplished very good crop yields may be secured. Small applications of farm manure will be valuable on newly drained areas. This material should not be applied, however, preceding the growing of the small grain crops. The type is acid and will respond to applications of lime. The use of a phosphate fertilizer would undoubtedly be profitable.

JUDSON SILT LOAM (131)

The Judson silt loam is a minor type in the county, covering only 0.1 percent of the total area. It occurs in several small areas along the Linn County line southeast of Urbana.

The surface soil of the Judson silt loam is a friable dark brown silt loam, extending to a depth of 10 to 12 inches. Below this point there are a few inches of a light brown, moderately compact, friable silt loam to silty clay loam, becoming lighter in color with increase in depth and at 28 to 30 inches assuming a yellowish-brown color. Commonly at about 36 inches there are some yellow and brownish mottlings. In topography the type is flat and smooth, sloping toward the first bottoms. Drainage is good.

The Judson silt loam is all under cultivation, corn, small grains and hay crops being grown. Yields of these crops are very much the same as those secured on the Waukesha silt loam. The needs of the soil for better crop production are very similar, also, to those recommended for the Waukesha types. The addition of farm manure would be profitable. The type is acid and will respond to liming and the use of a phosphate fertilizer would undoubtedly prove valuable.

SWAMP AND BOTTOMLAND SOILS

There are six swamp and bottomland soils in the county, classified in the Wabash, Cass and Sarpy series, and these with the areas of meadow and peat make a total of eight bottomland areas.

WABASH SILT LOAM (26)

The Wabash silt loam is the largest individual bottomland soil and the third largest soil area, covering 8.3 percent of the county. It occurs in extensive areas along practically all of the smaller streams, occupying the bottomland. Very little of the type is found along the Cedar River but some is mapped along the Iowa River. The largest developments of the type are along Eagle Creek south of Belle Plaine and along Prairie Creek in the southern townships.

The surface soil of the Wabash silt loam is very dark brown to nearly black friable silt loam, extending to a depth of 12 to 16 inches. Below this point there is a nearly black heavy silt loam or silty clay loam, grading at about 30 inches into a light grayish-brown compact, moderately plastic, silty clay, faintly mottled with brown and rusty brown. In some places the lower subsoil contains some sand especially on those narrow strips of the type near present or former stream courses. In some of these areas the soil may be almost a loam, and probably should be mapped as the Wabash loam but they are too small to show separately on the map and are included with the silt loam. In some places, along the smaller branches of the tributary streams, the soil is very much like the Clyde silt loam.

In topography the Wabash silt loam is nearly level to slightly sloping. The drainage is naturally poor and in many areas the type is subject to more or less frequent overflow. In places ditches and tile drains have been installed and have brought about considerable beneficial effects on the crop-producing power of the soil.

A large part of the type is utilized for pasture and excellent stands of bluegrass are usually maintained. A few trees, principally willow and elm, are found along the stream banks. Much of the type is not desirable for cultivated crops because of the poor drainage, the tendency to overflow and the fact that it occurs in narrow strips along the streams. On the larger areas the soil is cultivated and crop yields are quite satifactory in many seasons. Corn will yield 50 to 60 bushels per acre. Small grains give good yields but are apt to lodge.

The type needs adequate drainage first of all in order to be made more productive. Small amounts of farm manure would be valuable on newly drained areas, stimulating the production of available plant food. Manure should not be applied, however, preceding the planting of the small grain crops. The type is acid and lime would help for the growing of legumes. The use of a phosphate fertilizer would undoubtedly be profitable.

WABASH LOAM (49)

The Wabash loam is the second largest bottomland soil, covering 1.1 percent of the total area. It is found in a number of areas along many of the streams of the county. It is chiefly developed along Stein Creek, Wild Cat Creek and Big Creek and along most of the streams north of the Cedar River.

The surface soil of the Wabash loam is a dark brown to black compact, friable loam, extending to a depth of 12 to 14 inches. It usually contains large amounts of fine and very fine sand. The subsoil is a dark brown to bluish-black, compact, heavy loam or loamy clay. Brownish or yellowish-brown mottlings are found in places in the lower subsoil. In the area southeast of Shellsburg, the soil is a brown to dark brown friable fine sandy loam, underlaid by a light brown compact fine sandy loam, containing pockets of fine or medium sand and being somewhat lighter in color at the lower depths. In this area the soil should really be classified as a fine sandy loam but is included with the loam because of its small extent.

In topography the Wabash loam is nearly level and drainage is usually fair to good. In some of the shallow depressions drainage is not so well established and here the installation of tile would be valuable.

The Wabash loam is used mainly for pasture purposes and good stands of bluegrass are maintained. Along some stream channels there is a growth of willow, elm, sycamore, maple, or oak trees. The better drained areas are utilized for the growing of corn and other general farm crops, and yields are ordinarily quite satisfactory. On the cultivated portions of the soil beneficial effects would be secured from the application of small amounts of farm manure, the addition of lime to remedy acidity and the use of a phosphate fertilizer.

CASS LOAM (18)

The Cass loam is a minor type, covering only 0.6 percent of the area. It is found on the bottomlands along the Cedar River, being rather extensively developed in Taylor and Harrison Townships. A number of rather considerable areas of the type are found east and north of Vinton, and southeast of Mt. Auburn.

The surface soil of the Cass loam is a dark brown loam or silty loam, extending to a depth of 12 to 16 inches. There is a gradual change thru a layer of 4 to 6 inches into the subsoil which consists of a loamy fine sand or fine sandy loam, becoming lighter in color at the lower depths. Below 28 to 30 inches it is a light brown loamy fine sand. There are many variations in the soil. On some of the low ridges the loamy surface soil may be only a few inches in depth. In depressions or abandoned channels of the streams, the surface material may be almost three feet in depth in which case the type resembles the Wabash loam or silt loam. In general, however, loose sandy material is found at depths of 40 to 45 inches. In some places overflow waters have deposited sand on the surface of the soil.

The Cass loam is frequently overflowed and it is used almost entirely for pasture. There is some timber grown including bur and white oak, elm, birch, haw and willow. Bluegrass does well on the better drained areas. Prairie and coarse wild grasses grow in the swales and depressions. When well drained and protected from overflow good yields of general farm crops may be secured. The type will then respond to applications of farm manure, the use of lime and the addition of a phosphate fertilizer.

SARPY SAND (160)

The Sarpy sand is a minor soil type, covering only 0.5 percent of the total area. It is found in a number of areas along the Cedar River, the largest development of the type being in the vicinity of Vinton.

The surface soil of the Sarpy sand is a grayish-brown or light grayish-brown sand or loamy sand, extending to a depth of 6 to 7 inches. The subsoil is a whitish or yellowish-white, loose incoherent sand to a depth of 36 inches, and deeper. Some fine gravel is found in the lower soil and subsoil. Near the river the soil is more loose and sandy while on the more elevated spots the type is loamy and somewhat darker in color in the depressions. In some of the sharp bends in the river there are deposits of riverwash sand.

The Sarpy sand is subject to overflow and the surface is usually uneven owing to the shifting of the river waters. Drainage is excessive. The type has little agricultural value except for pasture.

WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is a minor soil type, covering only 0.2 percent of the total area. It is found in a number of small areas chiefly south of Belle Plaine and along a branch between Big and Rock Creeks.

The surface soil of the Wabash silty clay loam is a dark brown or grayish-black friable silty clay loam or clay loam, extending to a depth of 12 inches. Below this point the subsoil is a dark brown more compact clay loam or loamy clay becoming more compact in the lower depths. The lower subsoil is mottled with yellow, yellowish-brown or gray in places.

The surface of the type is flat and nearly level, and where associated with other bottomlands it is depressed. It occupies the beds of old sloughs and other depressions. It is subject to overflow and water stands on it for long periods. Drainage is poor and marshy conditions are common. The type is used largely for pasture and only a few areas are cultivated. When well drained and protected from overflow, it may be utilized for the growing of cultivated crops. It is acid and would respond to the addition of lime. The use of a phosphate fertilizer would undoubtedly be desirable. When newly drained a small amount of manure would be beneficial on the type. Manure should not be applied, however, preceding the growing of small grain crops.

CASS SANDY LOAM (19)

The Cass sandy loam is a minor soil type, covering only 0.2 percent of the total area. It is found in association with the Cass loam along the Cedar

River. Two of the principal areas are found northwest of Vinton on the north side of the river and northeast of Mt. Auburn.

The surface soil of the Cass sandy loam is a brown to dark brown sandy loam, extending to a depth of 14 to 16 inches. It contains more or less coarse sand and gravel. The subsoil is a lighter colored sandy loam, at 24 to 30 inches becoming a yellowish-brown incoherent sand or slightly loamy sand. In some places the texture of the surface soil varies to a fine sandy loam, and the depth of the surface material is extremely variable.

Most of the type is in pasture, some areas however, are used for general farm crops. When cultivated the soil will respond readily to applications of farm manure, or to the turning under of leguminous crops as green manures. It is acid in reaction and will respond to liming. The use of a phosphate fertilizer would undoubtedly be profitable and tests of acid phosphate are recommended.

MEADOW (20)

There is a small area of meadow, covering 0.1 percent of the total area. It is mapped along the Black Hawk County line on the bottoms of Big and Spring Creek along the Cedar River. Soil material mapped as meadow includes bottomland types so variable in texture, color and drainage condition that separation into types is impracticable. The principal soils in these areas are of the Wabash and Cass series, mainly loams and sands. Meadow is used almost entirely for pasture and there is some timber growth.

PEAT (21)

There is a small area of peat in the county, covering 0.1 percent of the total area. The most important area is found southwest of Mt. Auburn. There are some areas of less than one acre in extent which could not be shown on the map.

The surface material of peat consists of a brown to dark brown slightly decomposed vegetable matter mixed with small quantities of mineral material. In some places the layer of peat may extend to a depth of three feet or more. Shallower areas have a subsoil at a depth of 10 inches, consisting of a bluish-gray or dull yellow sticky plastic clay more or less mottled with brown and rusty brown. In the shallower and better decomposed peat areas, the soil resembles the Clyde types.

Peat is found in depressions which have formerly been ponds. The natural drainage is poor. The treatment which peat needs to reclaim it and make it productive is first of all thoro drainage. When this is accomplished it is usually desirable to seed to crops like timothy and alsike and pasture for several years in order to permit better decomposition of the peat material. The growing of corn and small grain crops on newly reclaimed peats is generally very unsatisfactory.

Where market conditions are desirable the growing of certain vegetable crops such as potatoes, tomatoes, onions and celery will be very profitable on well drained peat. In such cases the application of certain fertilizing materials would be valuable. Tests of fertilizing materials on peat when vegetable crops are grown are recommended.

APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment

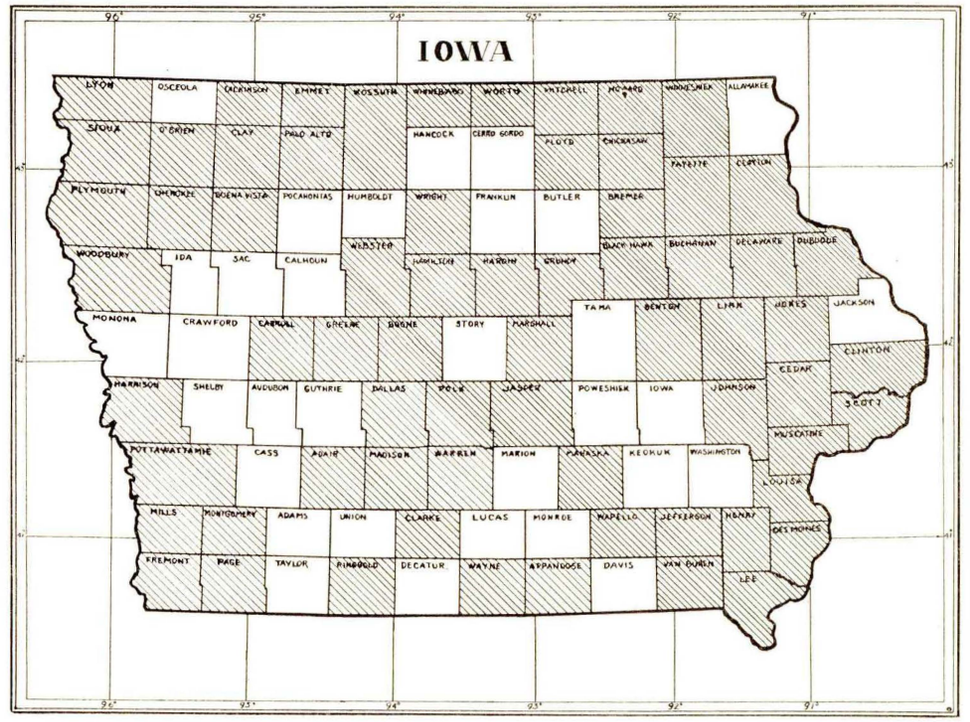

Fig. 7. Map of Iowa showing the counties surveyed.

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

PLANT FOOD IN SOILS

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

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

THE "SOIL DERIVED" ELEMENTS

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

AVAILABLE AND UNAVAILABLE PLANT FOOD

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

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

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

REMOVAL OF PLANT FOOD BY CROPS

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

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

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

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) t 16c (Sodium Nitrate ($NaNO_3$), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KC1)

Crop	Yield	Plant food, lbs.			Value of plant food			Total value of plant food
		Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	
Corn, grain.....	75 bu.	75	12.75	14	$12.00	$1.52	$0.34	$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
Barley, straw....	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop.....	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain....	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw....	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop.....	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain.....	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw.....	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop.....	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes.....	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay.....	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay....	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay.....	3 T.	120	15	90	19.20	1.80	5.40	16.40

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

REMOVAL FROM IOWA SOILS

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

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

PERMANENT FERTILITY IN IOWA SOILS

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

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

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

CULTIVATION AND DRAINAGE

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

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

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during the periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

THE ROTATION OF CROPS

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

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

MANURING

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

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

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

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

THE USE OF PHOSPHORUS

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

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

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

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 process constantly occurring in soils. Iowa soils are no exceptions 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.

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

SOIL AREAS IN IOWA

There are five large soil divisions in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 14.

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

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

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

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

THE SOIL SURVEY BY COUNTIES

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

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

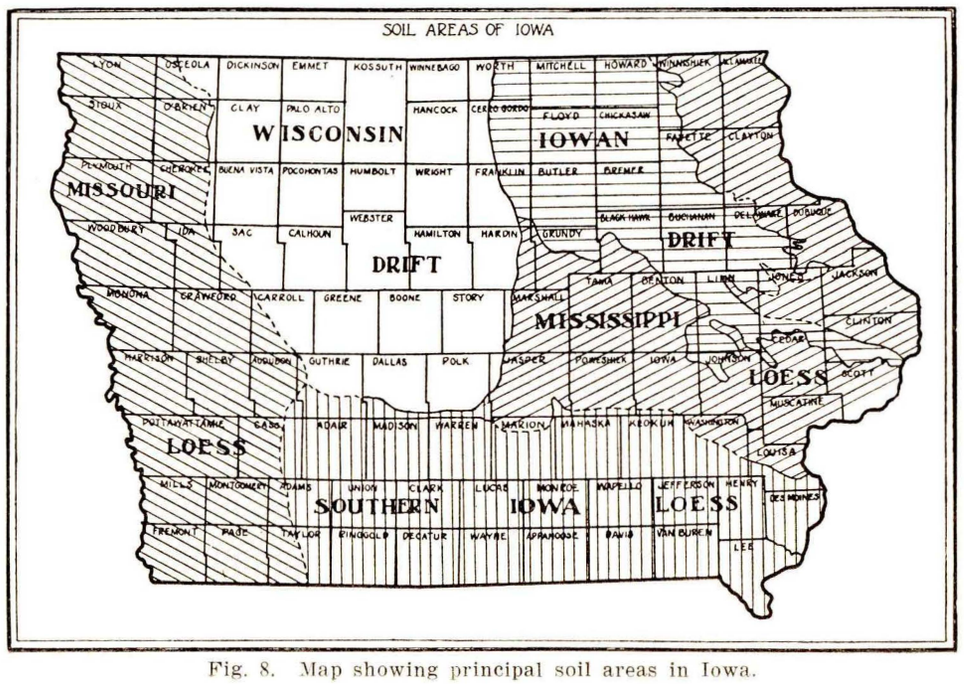

Fig. 8. Map showing principal soil areas in Iowa.

GENERAL SOIL CHARACTERISTICS

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

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

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

The common soil constituents may be given as follows:†

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

SOILS GROUPED BY TYPES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Gravels—More than 50 percent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

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

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

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

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

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

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

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

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