SOIL SURVEY OF IOWA

POLK COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 24

June, 1922

Ames, Iowa

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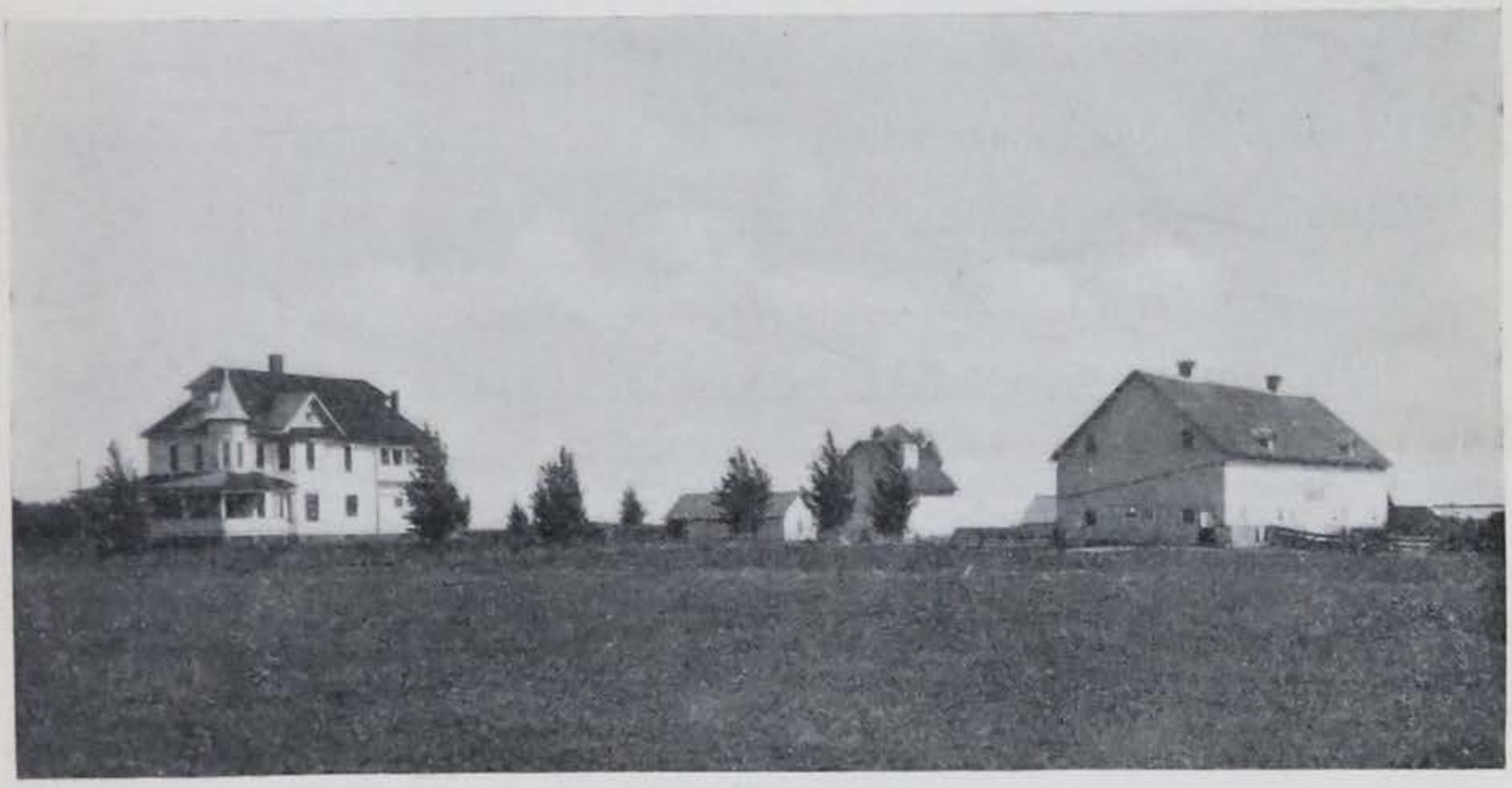
SOIL SURVEY OF IOWA

Report No. 24—POLK COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, G. E. Corson and C. J. Meister



A fine farm home in Polk county

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

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POLK COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, G. E. Corson and C. J. Meister

Polk county is located in south central Iowa, in the fourth tier of counties north of the Missouri state line, the sixth county east of the Missouri river and the seventh county west of the Mississippi river. It is partly in the southern Iowa loess and partly in the Wisconsin drift soil area and hence its upland soils are made up of loess and drift, the drift types occurring to a very much larger extent than do the loess soils.

The total area of the county is 582 square miles or 372,480 acres. Of this area 316,411 acres, or 84.9 percent, is in farm land. The total number of farms is 2,650 and their average size, 119 acres.

The following figures, taken from the Iowa Yearbook of Agriculture for 1920, show the utilization of the farm land of the county:

Acreage in general farm crops	213,679
Acreage in pasture	79,360
Acreage in farm buildings, feedlots and public highways	13,674
Acreage in waste land	7,311
Acreage in crops not otherwise listed	1,604

The type of agriculture practiced in Polk county at the present time consists mainly of general farming or a combination of grain farming and stock raising. Dairying and the feeding of beef cattle, however, are gradually becoming more popular. A large part of the grain produced in the county is fed on the farms and the livestock industry is gradually increasing. Polk county's agricultural income is derived from the sale of livestock, wheat, the surplus corn and other general farm crops. In the northeastern part of the county and in the vicinity of Grimes, shipping in livestock for feeding is quite common. Near Des Moines truck farming and a combination of truck farming and fruit farming are practiced to some extent. However, general farm crops are grown on the most of the farm land of the county.

There is a rather large area of waste land in the county which in many cases may be reclaimed and made productive. The methods of bringing such land under cultivation are varied and depend upon the particular condition which causes the infertility. No general recommendations can be given for the reclamation of these areas, but some method may be selected which will take care of the particular infertile condition. Special treatments which will prove profitable for individual soil conditions will be given later in this report. Advice regarding treatments most desirable in special cases may be obtained from the Soils Section of the Iowa Agricultural Experiment Station upon request.

THE FARM CROPS GROWN IN POLK COUNTY

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

*See Soil Survey Report of Polk County, Iowa, by E. H. Smies of the U. S. Department of Agriculture and Geo. E. Corson and Chas. J. Meister of the Iowa Agricultural Experiment Station.

TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN POLK COUNTY, IOWA

Crop	Acres	Percentage of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	117,500	37.10	50.0	5,875,000	$0.47	$2,760,250
Oats	48,500	15.30	39.0	1,891,500	0.36	680,940
Winter wheat	15,700	4.90	23.0	361,100	1.41	509,151
Spring wheat	10,000	3.10	13.0	130,000	1.35	175,500
Barley	100	0.03	33.0	3,300	0.63	2,079
Rye	820	0.22	15.0	12,300	1.17	14,391
Hay (tame)	17,430	5.50	1.3	22,660	16.24	367,998
Hay (wild)	2,490	0.78	1.2	2,988	12.69	37,907
Alfalfa	600	0.18	2.3	1,380	19.23	26,537
Potatoes	539	0.17	89.0	47,971	1.22	58,524
Pasture	79,360	25.00	....	.....	....	.....

Corn is the most important crop in the county, both in acreage and value. It is grown in all parts of the county and the average yield amounts to 50 bushels per acre. Most of the corn produced is from home grown seed and probably 70 percent is Reid's Yellow Dent. Boone County White is grown quite extensively in the county. A large part of the corn produced, estimated at around 65 percent, is fed to livestock on the farms. About 15 percent is sold to other farms for feeding purposes, and 20 percent is disposed of at local markets or shipped to outside markets, generally Chicago. The corn yields of the county are in general quite satisfactory. The dark colored upland soils and the better drained heavy bottomland soils which are protected from overflow frequently give very large yields. It will be noted that the average yield for the county is considerably higher than that for many Iowa counties.

Oats is the second crop in the county in acreage and value and average yields of 39 bushels per acre are secured. About 60 percent of the oat crop is made up of Silvermine and Iowa 103. Approximately 10 percent is composed of Kherson and Iowa 105 and Green Russian, White Russian and some other varieties are grown to some extent. About 65 percent of the oats produced is fed on farms to dairy cattle, calves and work stock. The remainder is sold to local markets and very little is shipped out of the county.

Wheat is the third crop in acreage and value in the county, by far the larger portion of the wheat grown being winter wheat. Average yields of winter wheat amount to 23 bushels per acre, while spring wheat gives an average yield of 13 bushels. Practically all of the winter wheat grown is of the Turkey variety, while the spring varieties used are Marquis and Early Java. Spring wheat has not been very largely grown in the county until recent years, but its acreage has increased considerably recently. Practically all of the wheat produced is disposed of at local flour mills.

The next crop in acreage and value is hay, most of it tame hay, with an average yield of 1.3 tons per acre. Wild hay is produced mainly on the low-lying, poorly drained soils of the Wabash and Bremer series and consists largely of slough grass. There are some areas of prairie grass and some bluegrass. The average yield of wild hay is 1.2 tons per acre. A large portion of the wild hay is sold for packing purposes. The finer varieties, the prairie grass and bluegrass hay, are utilized for feed. Over half of the tame hay produced consists of a

mixture of red clover and timothy; each of these crops is also grown alone on rather considerable areas.

Alfalfa is grown on a comparatively small area in the county, but this crop is becoming more popular as its value is being more generally recognized and more is learned regarding the methods of securing good stands. Average yields of 2.3 tons per acre are secured. More knowledge of the value of alfalfa for feeding purposes will certainly lead to a considerable increase in the acreage devoted to it, inasmuch as the crop will do well on most of the soils of the county.

Potatoes are grown rather extensively in the county and average yields of 89 bushels per acre are secured. The most important varieties are the Early Ohio, Irish Cobbler and Rural New Yorker. Some rye is produced, with average yields of 15 bushels per acre. Barley is a minor crop and of comparatively small value in the county. Millet and Sudan grass are grown on small areas and utilized for hay. Some sorghum is grown and utilized for sirup production.

Sweet corn is a rather important crop in the county, the principal varieties being Stowell's Evergreen and Country Gentleman. It is grown particularly in the vicinity of Altoona, Grimes and south of Maxwell (in Story county). It is utilized by the canning factory in Altoona and at Grimes and sold locally in Des Moines markets.

Sweet potatoes are grown on a small acreage on some of the sandy types of soil and other vegetables are produced on these soils in the vicinity of Des Moines. Watermelons and cantaloupes are grown very successfully on some of the upland types and on the sandy terrace soils.

Fruit growing is practiced to some extent in the county and there are numerous small orchards, chiefly apple orchards. At present there are six commercial orchards in the county ranging from 10 to 40 acres in size. The principal varieties are the Jonathan, Grimes and Ben Davis. Other varieties grown to some extent are the Winesap, Ralls, Blacktwig, Wealthy and Duchess. In 1920, according to the State Department of Agriculture, 93,759 bushels of apples were harvested in the county. The orchards which are carefully cared for, pruned and sprayed, as necessary, give very satisfactory yields. Cherries are grown to a considerable extent but there are no commercial cherry orchards. Grapes are produced rather extensively and there are five commercial vineyards ranging from one to seven acres in size. Some strawberries, raspberries and blackberries are grown, but chiefly for home use. Practically all of the fruit produced in the county is sold in the Des Moines markets.

THE LIVESTOCK INDUSTRY

The livestock industries of the county include the raising and feeding of hogs and beef cattle, dairying, the raising of horses, and the raising and feeding of sheep. Poultry production is also an industry of considerable importance.

The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the character and extent of the livestock industry of the county:

Horses, all ages	12,236
Mules, all ages	1,094
Swine (on farms July 1, 1920)	59,539
Swine (on farms Jan. 1, 1921)	48,447
Cattle (cows and heifers kept for milk)	10,585
Cattle (other cattle not kept for milk)	17,547

Cattle (all ages)	28,132
Sheep (all ages on farms January 1, 1921)	5,756
Sheep (shipped in for feeding, 1920)	2,009
Sheep (total pounds of wool clipped)	21,982
Poultry (total number on farms January 1, 1921)	275,650
Poultry (number of dozen eggs received 1920)	1,027,949

The raising of purebred hogs is an important industry in the county, the most popular breeds being Poland China, Duroc Jersey and Chester White. Recently there has been some breeding of Hampshires. Many hogs are fattened, large numbers being shipped in for feeding, particularly on farms where cattle are fed. Practically all of the hogs sold go to the Des Moines markets.

Beef cattle are raised to some extent in the county, only a few of them, however, being purebred. There are some purebred Shorthorn and Aberdeen Angus herds, but most of the beef cattle are grade Shorthorns. Most of the beef cattle are raised locally, but some are shipped in for fattening, particularly in the northeast corner of the county and near Grimes. Practically all of the beef cattle sold in the county are disposed of at the packing houses in Des Moines.

Dairying is becoming important in the county. There are many dairy farms and in many cases dairying is combined with general farming. The largest dairy farms have purebred stock, and in all there are about 100 purebred herds in the county. The most popular breeds are the Holstein and Shorthorn, altho there are a number of Jersey and Guernsey herds. The county has a large number of silos and ensilage is an important feed. Most of the milk produced is sold to the distributing companies in Des Moines.

Sheep raising is practiced to some extent and the fattening of sheep is becoming an important practice, particularly near Grimes, where several carloads of western sheep are shipped in each year. Nearly every farmer raises one or more colts and the important breeds are the Percheron and Belgian. Very few draft horses are produced in excess of the home demand, however, and this industry has not been developed to any considerable extent.

GENERAL SOIL CONDITIONS

Crop yields in Polk county are in general very satisfactory, but there are many instances where larger crops could be secured and where the fertility of the soil could be better maintained if proper methods of soil treatment were followed.

In some instances drainage conditions are not entirely satisfactory and the installation of tile would increase crop yields. The drainage system of the county in general is quite adequate and hence it is usually a question of laying a small amount of tile to bring about an entirely satisfactory drainage condition.

Many of the soils of the county are acid and should have applications of lime for the best growth of crops, particularly of legumes. There are many cases where lime is not needed, but it is usually impossible to determine this fact without making special tests. It is very desirable, therefore, that the soils of the county be tested for acidity, particularly the upland types.

The organic matter contained in many of the soils is not sufficient to insure the best crop production and applications of farm manure or the use of green manure crops are needed. Even on the types which are apparently better supplied with organic matter, applications of farm manure have been found to be of value and should be used liberally. This is particularly true on the sandy

upland and terrace soils which are utilized for trucking purposes. In fact, where truck crops are to be grown, especially liberal applications of farm manure are very desirable. In all cases where the production of farm manure is inadequate to supply the soils, leguminous green manure crops may be used to advantage. Crop residues should always be returned to the soil in order to aid in keeping up the organic matter supply.

The amount of phosphorus in the soils of the county is somewhat variable but in most instances it is rather low and on some of the types, therefore, there is no question but that phosphorus fertilizers will be needed in the very near future, even if they do not prove of value now. On some of the types the supply is much larger and probably these soils will not respond to phosphorus at the present time. There is no method by which the need of phosphorus can be determined except by applying it to small areas and determining the effect on crop yields. Field tests are now under way in the county to determine the need of phosphorus on the more important soil types, but results from these tests are not yet available. For the present, therefore, it can merely be suggested that farmers make tests of phosphorus on their own soils to determine whether these fertilizing materials can be used with profit. They may use both acid phosphate and rock phosphate in such tests and thus determine not only the need of phosphorus, but also which material should be used.

Complete commercial fertilizers may also be tested along with the phosphorus carriers, but their use is not recommended for general farm crops at the present time. If they prove of value on small areas, then they may be applied to large areas with the assurance of profit. There is no objection to the use of complete commercial fertilizers if they prove profitable. These materials frequently do show a profit in truck farming and their use under truck farming conditions may be very desirable.

In some cases erosion is active in the county and demands some method of control. From the methods suggested in a later section of this report one may be chosen which will serve under almost any soil conditions.

THE GEOLOGY OF POLK COUNTY

The geological history of Polk county prior to the invasion of the county by the glaciers is of practically no significance in a consideration of its soils. The original bedrock material has been covered by various glacial deposits to such great depths that the soils of the county are not influenced by the character of the underlying rock material.

Two great glaciers invaded Polk county. Each left behind vast deposits of glacial drift or till. The first of these, known as the Kansan, covered the entire surface of the county and buried the native rock material under a deep deposit. The Kansan drift consists largely of a stiff blue clay containing numerous pebbles and small boulders. Pockets of sand and gravel occur in or above this layer of clay and where the drift has been exposed to weathering, it has changed to a brown or red color thru oxidation. This drift material is exposed at the surface in a few cases in the southern part of the county, where the subsequent drift deposit and the loess covering have been removed. The soils known as the

Shelby loam and the Lindley fine sandy loam are derived in whole or in part from this Kansan till. These types are both of minor importance in the county and occur under rather rough topographic conditions.

Following the Kansan glaciation, a second great glacier, known as the Wisconsin, covered the northern four-fifths of the county. The drift layer left by this glacier is quite variable in thickness, ranging from 75 feet in the northern part of the area to a few feet at its southern boundary. This drift material is made up of a mixture of clay, silt and sand, with occasional beds of gravel. Two thick beds of gravel are found, one west of Crocker and the other east of Kelsey. Boulders and pebbles occur scattered thruout the drift material and many of the boulders are rather large. In its natural state the drift is bluish-gray to pale yellow in color and it originally contained considerable calcareous material. Thru the process of weathering, however, the carbonates have been very largely washed out in the drainage water except where the soils have been developed under a level topographic condition. The soils derived from this Wisconsin drift material are classified in the Carrington and Webster series, the latter occurring in the more level areas and characterized by a much higher content of organic matter, a blacker color and considerable amounts of carbonates. The Carrington soils are lighter in color and have lost the greater portion or all of their carbonate content.

Above the drift in the southern part of the county there has been deposited a thin covering of a silty material known as loess. This is supposed to have been deposited by the wind at some previous geological time when climatic conditions were very different than at present. About one-fifth of the county is covered by the loess, extending from the western boundary, where it is three and one-half miles in width, over a gradually widening area to the eastern boundary, where it is about nine miles wide. It varies considerably in depth, averaging from 10 to 20 feet. It is characterized by a buff color and the absence of pebbles and boulders. A few small pockets of sand are occasionally found, but these are of very minor occurrence. Originally this loessial material was probably well supplied with lime nodules but at the present time these have all been removed by leaching and the soils are acid. The soils derived from this loessial material are classed in the Tama and Clinton series. The Tama silt loam is the most important loess type and occupies a rather extensive acreage. The Clinton silt loam is of minor occurrence. The former type is characterized by an undulating to gently rolling topography, while in the case of the Clinton soils the topography is rolling to rough. The Tama silt loam has been produced from the weathering and accumulation of organic matter in this loess covering under prairie conditions. Hence it is rather dark in color. The Clinton silt loam, on the other hand, has been produced under forested conditions and the color is much lighter.

The terrace and bottomland soils of the county are derived from the reworked glacial and loessial material of the upland. The older and higher terraces are found in the Wisconsin drift region and they lie 15 to 40 feet above the present flood plain of the larger streams. These soils are extremely variable in texture and in some instances are characterized by layers of sand and gravel, while in other cases the lower layers are heavy and made up mainly of clay. These older terraces are grouped in the O'Neill, Waukesha, Buckner and Chariton series.

BOONE CO.

R. 25 W.

STORY CO.

R. 24 W.

R. 23

T. 81 N.

T. 80 N.

T. 79 N.

T. 78 N.

DALLAS CO.

WARREN CO.

R. 25 W.

R. 24 W.

Kelsey

Zeldahl

Polk City Jct.

Polk City

Allemans

Ankeny

Ankeny

Orchabor

Ewer

Berwick

Yoder

Saylorville

Saylor

Johnston

Grimes

Camp Dodge

Urbandale

Clive

Campbell

Rider

Lovington

Norwoodville

Bowsher

Highland Park

Eastern Place

Valley Junction

Commerce

Park Avenue

Avon

Fort Des Moines

DES MOINES

SOIL MAP OF POLK COUNTY

LEGEND

Drift Soils

- 1 — Carrington loam
- 56 — Webster clay loam
- 107 — Webster silty clay loam
- 449 — Carrington loam (Shallow phase)
- 4 — Carrington fine sandy loam
- 136 — Lindley fine sandy loam
- 79 — Shelby loam

Loess Soils

- 145 — Tama silt loam (Shallow phase)
- 120 — Tama silt loam
- 80 — Clinton silt loam
- 148 — Tama loamy fine sand

Terrace Soils

- 60 — Waukesha loam
- 43 — Bremer silty clay loam
- 103 — O'Neill fine sandy loam
- 88 — Bremer silt loam
- 12 — Bremer loam
- 45 — Buckner fine sandy loam
- 75 — Waukesha silt loam
- 106 — O'Neill loam
- 44 — Bremer clay
- 146 — O'Neill fine sand
- 105 — Chariton silt loam

Swamp and Bottomland Soils

- 72 — Wabash clay
- 48 — Wabash loam
- 91 — Sarpy loam
- 111 — Lamoure silty clay loam
- 144 — Sarpy silty clay loam
- 28 — Sarpy very fine sandy loam
- 48 — Wabash silty clay loam
- 26 — Wabash silt loam
- 89 — Sarpy silt loam
- 53 — Riverwash
- 21 — Muck and Peat
- 62 — Wabash fine sandy loam
- 102 — Sarpy fine sandy loam

Scale: 1 Inch 2½ Miles

The more recent terraces are 5 to 15 feet above the present overflow land and they are grouped mainly in the Bremer series. The bottomland types of the county are sandy in some cases, particularly along the first bottoms of the Des Moines river and its tributaries. Along the Skunk river the texture is heavy. In the southern part of the county the soils are mainly silt loams. The bottomland soils are grouped in the Wabash, Sarpy and Lamoure series.

PHYSIOGRAPHY AND DRAINAGE

Polk county is in general a rather level to gently rolling drift covered or loess covered plain. The drift uplands thruout the county are flat to gently undulating, while the loess uplands are distinctly rolling. In the northwestern part of the county in the drift area a few knolls which are low and of small extent occur on the level upland. The rolling topography of the loess area is found in the southern part of the county. Hence there are two rather distinct topographic divisions in the county, one in the drift covered region and one in the loess area.

Except along the Des Moines river, the slopes to the larger streams in the drift covered region are very gradual. Along the smaller drainage ways there is very little slope and the streams occupy shallow depressions in the upland. Along the Des Moines river the topographic condition has been modified somewhat by erosion. In the main the slopes are gradual but in some sections the gently undulating uplands extend very close to the present river flood plains and there is an abrupt drop from the upland. The areas between the drainage ways thruout the drift covered region are however quite level. In the loess covered area the slopes to the streams are relatively steep and the divides between the streams are narrow and more rolling in topography.

The terraces of the county are usually nearly flat, altho in some of the older ones erosion has occurred to some extent and they appear slightly undulating. The bottomlands along the river courses are level and broken only by the old channels of the streams.

The county is drained by the Des Moines river with its tributaries, and the Skunk river. The Des Moines river has a channel varying from 300 to 600 feet in width. Above the mouth of the Raccoon river the valley is narrow and steep-sided, while below it is broad and has a well developed flood plain. The flood plain of the river lies 120 to 140 feet below the general level of the upland and varies from one-fourth to one and one-half miles in width in its upper course, to three to four miles in the lower portion.

The Raccoon river is one of the principal tributaries of the Des Moines. It enters the county near the southwest corner and with Walnut creek, its principal tributary, drains a large portion of the county. The channel of this river varies from 100 to 200 feet in width and the flood plain is about a mile wide.

Beaver creek is an important tributary of the Des Moines river to the west and has a flood plain of about one-fourth of a mile in width. East of the Des Moines river there are several large tributaries, mostly flowing in a direction parallel to the river itself. Big creek is found in the northwest portion of the county. Four Mile creek is a large tributary joining the river south of Des Moines and extending north almost thru the center of the county. Saylor

creek and Rock creek are minor tributaries west of Four Mile creek. Mud creek and Camp creek drain the southeastern portion of the county, the former joining the Des Moines river at the edge of the county and the latter flowing into Jasper county.

Skunk river crosses the county in the northeast corner. It flows in a narrow channel and has a flood plain averaging nearly two miles in width. The valley slopes are gradual and the uplands are about 60 to 80 feet above the flood plain. This river, with its most important tributary, Indian creek, drains the northeastern portion of the county.

The drainage of the county is well established in the vicinity of the Des Moines river and the Skunk river and also along Indian and Beaver creeks. The areas along the lower courses of Four Mile creek, Rock creek and Saylor creek are likewise well drained but in considerable areas of the more level upland occurring between the Skunk river and the Des Moines river in the central part of the county and in the western part of the county between Grimes and Walnut creek,

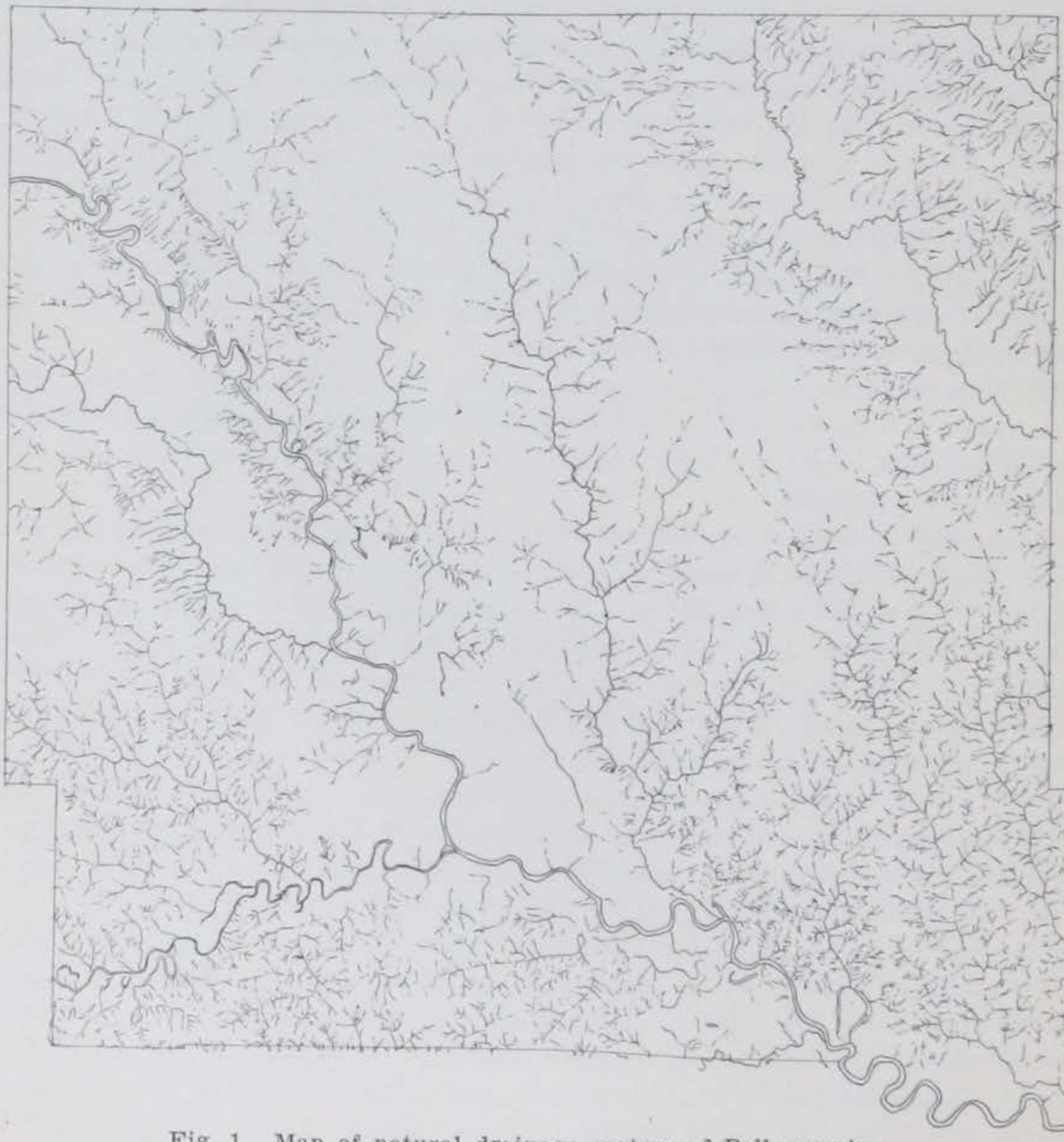

Fig. 1. Map of natural drainage system of Polk county.

drainage is poorly developed and there are many farms that are still in need of tiling. Much of these areas just mentioned was originally in a marshy condition and there are many meandering sloughs which eventually empty into the larger streams. The fall, however, is slight and in most instances the natural drainage in these areas is very poor. Along the steeper slopes of the Des Moines river drainage is often excessive. There is very little of the county, however, in which this is true.

The natural drainage system of the county is shown in the accompanying drainage map, and the areas of poor drainage are very largely indicated, altho it would seem from the map that drainage should be more satisfactory in some areas than is actually the case. This is due to the fact that there is so little fall in many of the intermittent drainage channels that the water moves down them at a very slow rate and consequently the land retains considerable amounts of moisture over long periods of time.

THE SOILS OF POLK COUNTY

The soils of Polk county are grouped into four classes according to their origin and location. These are loess soils, drift soils, terrace soils and swamp and bottomland soils. Loess soils are fine, dust-like deposits made by the wind at some time when climatic conditions were different that at present. Drift soils are deposits left by glaciers upon their retreat and they are made up of material from various sources and contain sand, gravel and boulders. The terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the stream which deposited them or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams and they are subject to more or less frequent overflow. The extent and occurrence of these four groups of soils in Polk county are shown in table II.

Over one-half of the total area of the county, 60.1 percent, is covered by drift soils. The loess soils are second in area, covering 14.5 percent of the county. Terrace soils are minor in extent, covering 11.4 percent of the county, while the swamp and bottomland soils are rather extensive, covering 14.0 percent of the total area of the county.

There are 31 individual soil types in the county, and these with the shallow phase of the Carrington loam and the shallow phase of the Tama silt loam and the areas of riverwash and muck and peat, make a total of 35 separate soil areas.

There are six drift soils in the county, and a small area of the shallow phase of the Carrington loam, making a total of seven drift soils. There are three loess types and an area of the shallow phase of the Tama, making four loess soils. There are eleven terrace types and eleven swamp and bottomland types which, together with the areas of riverwash

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

Soil Group	Acres	Percent of total area of county
Drift soils	223,232	60.1
Loess soils	54,528	14.5
Terrace soils	42,368	11.4
Swamp and bottom land soils	52,352	14.0
Total	372,480	....

and muck and peat, make thirteen bottomland soils. These various soils are distinguished on the basis of certain characteristics which are described in the appendix to this report and the names denote certain group characteristics.

The areas of the various soil types of the county are shown in table III. The Carrington loam is by far the largest individual soil type as well as the largest drift soil. The Webster clay loam is the second largest drift type and it is the second type in area in the county, covering 17.0 percent of the total area. The Tama silt loam is the largest loess type and the third largest type in the county. The terrace types are all minor in area, the largest being the Waukesha loam, which covers 3.7 percent of the county.

The swamp and bottomland soils in the county are likewise all small in area, the most extensive being the Wabash clay, which covers 4.1 percent of the county.

The uplands of the county are covered by the drift and loess soils and in the case of the former types the topography is almost level to gently undulating. Where the loess soils occur, however, in the southern part of the county, the

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN POLK COUNTY, IOWA

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
1	Carrington loam	118,656	32.9
142	Carrington loam (shallow phase)	3,584	
56	Webster clay loam	63,168	17.0
107	Webster silty clay loam	16,256	4.4
4	Carrington fine sandy loam	9,280	2.5
136	Lindley fine sandy loam	6,976	1.9
79	Shelby loam	5,312	1.4
	LOESS SOILS		
120	Tama silt loam	37,056	11.1
143	Tama silt loam (shallow phase)	4,608	
80	Clinton silt loam	12,352	3.3
145	Tama loamy fine sand	512	0.1
	TERRACE SOILS		
60	Waukesha loam	13,696	3.7
43	Bremer silty clay loam	6,656	1.8
110	O'Neill fine sandy loam	4,928	1.3
88	Bremer silt loam	4,480	1.2
12	Bremer loam	3,328	0.9
45	Buckner fine sandy loam	2,752	0.7
75	Waukesha silt loam	2,560	0.7
108	O'Neill loam	2,048	0.6
44	Bremer clay	1,088	0.3
146	O'Neill fine sand	512	0.1
105	Chariton silt loam	320	0.1
	SWAMP AND BOTTOMLAND SOILS		
72	Wabash clay	15,168	4.1
49	Wabash loam	8,512	2.3
91	Sarpy loam	6,464	1.7
111	Lamoure silty clay loam	5,184	1.4
144	Sarpy silty clay loam	4,800	1.3
28	Sarpy very fine sandy loam	3,328	0.9
48	Wabash silty clay loam	2,816	0.8
26	Wabash silt loam	1,920	0.5
89	Sarpy silt loam	1,280	0.3
53	Riverwash	896	0.2
21	Muck and peat	832	0.2
62	Wabash fine sandy loam	640	0.2
102	Sarpy fine sandy loam	512	0.1

topography is more rolling. Hence the Tama silt loam has a characteristic rolling topography and the Clinton silt loam is strongly rolling to rough. The drift types of the Webster and Carrington series on the other hand vary from level to gently rolling.

Along the streams of the county the topography is quite different than on the uplands which separate the streams. Frequently the rivers flow thru deep valleys with sharply rising bluffs leading to the uplands. In some areas erosion has been very active and the loess covering and the more recent drift layer have been washed away, exposing the earlier drift formation. Here the soils of the Shelby and Lindley series are found and these are characterized by a strongly rolling to steep or rough topography.

The terraces and bottomlands are usually rather level, altho in some cases the terraces have been eroded to some extent and do not appear as level as would be expected. The bottomlands are very largely subject to overflow and in some instances are poorly drained.

The need of drainage is apparently very closely related to the topographic conditions of the soils in the county. The more level drift soils and the bottomland soils are poorly drained in many instances, while the rolling drift types and the loess soils are quite adequately drained.

THE FERTILITY IN POLK COUNTY SOILS

Samples were taken for analyses from each of the soil types in the county, except the shallow phase of the Carrington loam. The areas of muck and peat and riverwash were not sampled, because the analyses of these materials would be of very little significance. The more extensive types were sampled in triplicate, while one sample only was taken in the case of the minor types.

All samplings were made with the greatest care that the soils should be representative and that variations due to local conditions and special treatments should be eliminated. Samplings were made at three depths, 0 to 6 2/3 inches, 6 2/3 to 20 inches and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil, respectively. The samples were analyzed for total phosphorus, nitrogen, organic carbon, inorganic carbon and limestone requirement. The official methods were employed for the phosphorus, nitrogen and carbon determination and the Veitch method was employed in determining the limestone requirement. The figures given in the tables are the averages from the results of duplicate determinations on all samples of each type and they represent, therefore, the averages of four or twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soil are given in table IV. They are calculated in pounds per acre on the basis of 2,000,000 pounds of surface soil per acre.

The phosphorus content of the soils of the county is quite variable, ranging from 1,043 pounds in the Tama loamy fine sand up to 3,360 in the Bremer clay. The latter amount, however, is considerably higher than that found in most of the types in the county. There seems to be practically no relation between the phosphorus supply and the soil group, altho the bottomland types on the average

TABLE IV. PLANT FOOD IN POLK COUNTY SOILS

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

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	1,436	3,941	45,306	0	4,204
56	Webster clay loam	1,723	5,636	68,086	1,360	Basic
107	Webster silty clay loam	2,101	9,836	114,816	22,104	Basic
4	Carrington fine sandy loam	1,252	1,710	19,960	0	5,005
136	Lindley fine sandy loam	1,205	2,074	36,266	Trace	Basic
79	Shelby loam	2,175	2,858	33,840	0	2,145
	LOESS SOILS					
120	Tama silt loam	2,040	4,176	48,260	0	4,290
143	Tama silt loam (shallow phase)	1,151	2,396	25,000	0	2,502
80	Clinton silt loam	1,764	3,278	35,460	0	1,430
145	Tama loamy fine sand	1,043	2,088	33,420	0	2,145
	TERRACE SOILS					
60	Waukesha loam	3,024	2,886	34,140	0	4,290
43	Bremer silty clay loam	2,889	4,624	61,220	0	3,932
110	O'Neill fine sandy loam	1,508	2,326	28,880	0	3,932
88	Bremer silt loam	2,161	4,554	65,420	0	3,932
12	Bremer loam	1,737	2,564	32,940	0	715
45	Buckner fine sandy loam	1,616	2,283	21,620	0	4,747
75	Waukesha silt loam	1,953	3,978	47,640	0	3,575
108	O'Neill loam	1,899	3,516	36,280	0	5,005
44	Bremer clay	3,360	6,094	81,390	1,070	Basic
146	O'Neill fine sand	1,245	1,050	6,360	0	2,502
105	Chariton silt loam	1,656	3,810	45,540	0	5,005
	SWAMP AND BOTTOMLAND SOILS					
72	Wabash clay	2,343	4,442	60,308	532	Basic
49	Wabash loam	2,289	2,984	32,846	3,094	Basic
91	Sarpy loam	1,865	2,732	30,121	9,039	Basic
111	Lamoure silty clay loam	2,330	7,888	89,044	11,696	Basic
144	Sarpy silty clay loam	1,501	2,900	33,494	11,646	Basic
28	Sarpy very fine sandy loam	2,155	1,556	15,544	18,596	Basic
48	Wabash silty clay loam	2,916	3,236	38,936	644	Basic
26	Wabash silt loam	2,276	3,670	42,920	0	4,747
89	Sarpy silt loam	1,865	2,844	28,500	440	Basic
62	Wabash fine sandy loam	1,993	1,836	31,600	4,540	Basic
102	Sarpy fine sandy loam	1,495	1,304	14,944	Trace	Basic

are somewhat better supplied with this constituent than the terrace and upland soils. This condition would be expected, inasmuch as many of the bottomland soils have been uncultivated and uncropped and hence there has been very little removal of phosphorus. The drift soils on the average seem to be somewhat better supplied with phosphorus than the loess soils, while the terrace types are extremely variable. There seems to be more of a relation between the soil texture and the phosphorus supply than is true in the case of the soil groups. In a general way the sandier types are lower in phosphorus, while the clay soils are much better supplied. The Carrington fine sandy loam is lower in phosphorus than the Carrington loam. The Tama loamy fine sand is very much lower than the Tama silt loam, containing the least amount of phosphorus of any type in the county. The O'Neill fine sand is lower in phosphorus than the fine sandy loam of the same series and this in turn is lower than the O'Neill loam. There is only one exception to this general rule and that is in the case of the Sarpy very fine sandy loam, which is particularly high in phosphorus, higher even than

the loam and silt loam. This, however, is an abnormal condition and other factors than the soil texture are involved in the composition of this soil, which is a minor bottomland type. In the case of the other types in this series there seems to be some relation to the soil texture. Thus the Sarpy fine sandy loam contains less phosphorus than the Sarpy loam and also a smaller amount than the silt loam.

There seems to be some relation, too, between the phosphorus supply and the soil series. The Webster soils of the upland are higher than the Carrington soils and the Lindley series is particularly low. The Tama soils of the loessial upland are better supplied than the Clinton areas. The Bremer and Waukesha soils of the terraces are very much higher in phosphorus than the O'Neill and Buckner types and among the bottom types the Wabash soils and the Lamoure soils are in general higher in phosphorus than the Sarpy series. There is undoubtedly some relation here between the particular characteristics of the soils which determine the series in which they are placed and the phosphorus supply.

It is quite evident that there is no large supply of phosphorus in any of the soils of the county, and phosphorus fertilizers will undoubtedly be needed in the near future if the soils are to be kept satisfactorily productive. It may be that applications of phosphorus fertilizers would prove of considerable value at the present time in some instances. Even altho there is an abundance of phosphorus present in a soil, there may be a lack of the element in an available form and where this is true the application of a soluble fertilizer would prove of considerable economic value. There is no way to determine accurately the amount of available phosphorus in the soil except to apply a soluble phosphorus fertilizer and determine its effect on crop yields. If it brings about an increase then the conclusion may be drawn that available phosphorus is lacking in the soil. Such tests are strongly urged. On the individual farm they are of particular value in showing the needs of individual soils and they also permit of conclusions regarding the relative value of the various phosphorus carriers, and particularly, rock phosphate and acid phosphate.

The total nitrogen content of the soils of the county is quite variable, ranging from 1,050 pounds per acre in the O'Neill fine sand up to 9,836 pounds in the Webster silty clay loam. In some instances there seems to be an abundance of nitrogen, but in most of the types the amount present is sufficient to keep crops supplied for only a short time.

There is no apparent relation between the nitrogen content and the soil group. The bottomland soils, which are ordinarily better supplied with nitrogen than the other groups, show about the same average amount as the uplands. The same is true of the terrace types. There is some relation, however, between the soil texture and the soil series and the nitrogen content. The Webster soils are higher in nitrogen than the Carrington soils. The Tama soils are higher than the Clinton types; the Bremer and the Waukesha soils on the terraces are generally higher than the O'Neill series. The Wabash and Lamoure soils of the bottomlands contain more nitrogen than the Sarpy soils. There are some exceptions to these comparisons, however. For example, the O'Neill loam on the terrace is higher than the Waukesha loam and it is also higher than the Bremer loam, but in general the soils of this series are lower than the others.

As to soil texture and nitrogen content, the heavier textured soils contain more nitrogen in most cases than the lighter textured types. Thus, the Carrington fine sandy loam is lower than the Carrington loam. The Tama loamy fine sand is lower than the silt loam. The Bremer loam is lower than the silty clay loam and the clay. The Waukesha loam is lower than the silt loam. The O'Neill fine sand is lower than the O'Neill loam and among the bottom types the Wabash loam is lower than the silt loam, silty clay loam and clay, while the Wabash fine sandy loam contains less nitrogen than the loam.

The analyses of these soils as a whole show that nitrogen must not be disregarded in systems of permanent soil fertility in this county. With the exception of a very few of the types, precautions should be taken at once to see that the nitrogen supply is built up. Where the nitrogen supply is inadequate, crops may be unsatisfactory for this reason. Farm manures and crop residues return to the soil some nitrogen and aid materially in keeping up the content of this element. They do not return all of the nitrogen removed by crops, however, and even when they are employed, the nitrogen supply in the soils gradually decreases. Leguminous crops turned under as green manures are often necessary in addition to farm manures and crop residues to build up and maintain the nitrogen content of the soil. When these crops are well inoculated they take from the atmosphere a large part of the nitrogen which they contain. When they are turned under, this nitrogen becomes available for the use of subsequent crops, providing a cheap and very desirable method of adding nitrogen to the soil. This method should undoubtedly be followed to some extent in keeping up the nitrogen in Polk county soils.

The organic carbon content of the soils is always very closely related to the nitrogen content and the supply of both bears a definite relation to the color of the soil. If the soil is dark in color it is well supplied with organic matter and usually also with nitrogen. On the other hand, if it is light in color the organic matter content is low and nitrogen is probably deficient. The ratio of nitrogen to organic carbon in soils gives some indication of the extent or rapidity of the decomposition processes and hence of the rate of production of available plant food. If the decomposition of the organic matter in soils is too slow plants may suffer from a lack of available plant food. If the amount of carbon in relation to nitrogen falls below a certain ratio, it may be rather definitely concluded that the production of available plant food is not proceeding satisfactorily.

On most of the soil types in Polk county the relation between the nitrogen and organic carbon is such that it is quite certain that the decomposition of the organic matter is going on quite satisfactorily. There are a few exceptions to this, particularly in the case of some of the lighter textured types where the total supply of organic matter is too low. In all these cases it is especially necessary that farm manure be used. This material stimulates the production of available plant food besides adding organic matter. Where farm manure is not available in sufficient amounts, leguminous green manures should be used as supplements. Crop residues should be utilized in all cases. Even on some of the types apparently better supplied with organic matter, the application of farm manure has been found to be of value, probably due to the fact that it stimulates the production of available plant food. But whatever the reason for its beneficial effect,

Fig. 2. Level Webster clay loam topography.

it is certain that the use of this fertilizing material on most of the soils of the county pays.

In handling practically all of the soils of Polk county, care needs to be taken to keep up the supply of organic matter. Too much emphasis cannot be placed upon the proper use of crop residues and the proper preservation and application of all the manure produced on the farm, and if these materials are inadequate, the use of leguminous crops as green manures.

The upland soils of the county, with the exception of those in the Webster series, are generally acid and contain no inorganic carbon. The Lindley fine sandy loam does not appear to be acid in this particular test, but this is not generally true for this soil type. The Webster soils are usually not acid and contain at least small amounts of lime. They may need a small application of lime when the surface soil is acid and this sometimes occurs. The subsoils of the types of this series are never acid, but if the surface soil is acid, lime should be applied. The loess types are all acid and all but one of the terrace types are acid and in need of lime. Of the bottomland soils of the county only one type shows acidity according to the tests. Some others of the soils tested here do, however, show an acid reaction in other samples, especially the Wabash soils. It is apparent from the results that all of the upland types except those of the Webster series and all of the terrace types should be tested for acidity and the lime shown to be necessary by the tests should be applied if the crops grown are to be satisfactory. This is particularly true in the case of legumes. The bottomland types of the county apparently are not in need of lime at present except in a few instances.

The figures given in the table showing the lime requirements of the soils are merely indicative of the needs of the various types and should not be taken to show definitely how much lime these soils will need. The lime requirement of soils is extremely variable, even under apparently identical conditions. Hence the soil from every field should be tested for lime requirement before any appli-

cation is made. There is no question but that the best crop growth, especially of legumes, cannot be secured on many of the soils in Polk county unless they are tested and lime is applied. In fact, with only one exception, there is not sufficient lime content in the upland soils or terrace types to keep this material from becoming deficient in the near future and in four of the bottomland types the lime supply is low and will soon be lacking.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the surface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil. In general, the plant food content of the lower layers of soil has very little influence on the fertility of the soil and on the treatments needed unless there are some large amounts of plant food constituents present. In the soils of Polk county the subsurface soils and subsoils are not any higher in any constituent than the surface soils and in most cases the content of plant food constituents is less. Hence it is unnecessary to consider these analyses in detail.

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

Pounds per acre of Four Million Pounds of Subsurface Soil (6 2-3"—20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	2,541	4,950	50,507	0	4,528
56	Webster clay loam	2,828	4,997	61,844	1,656	Basic
107	Webster silty clay loam	3,367	12,748	138,344	38,176	Basic
4	Carrington fine sandy loam	2,397	3,084	37,560	0	9,495
136	Lindley fine sandy loam	2,007	2,408	25,400	0	1,430
79	Shelby loam	3,987	3,728	41,920	680	Basic
	LOESS SOILS					
120	Tama silt loam	3,596	7,284	79,320	0	6,434
143	Tama silt loam (shallow phase)	2,087	3,392	29,600	0	5,004
80	Clinton silt loam	2,411	3,140	27,240	0	5,720
145	Tama loamy fine sand	2,505	3,840	33,400	0	3,574
	TERRACE SOILS					
60	Waukesha loam	3,825	5,520	62,360	0	8,580
43	Bremer silty clay loam	4,337	6,472	61,220	0	6,434
110	O'Neill fine sandy loam	2,465	4,652	50,080	0	5,720
88	Bremer silt loam	3,987	7,844	100,840	0	7,864
12	Bremer loam	2,491	9,136	141,756	724	Basic
45	Buckner fine sandy loam	2,357	4,567	50,320	0	5,720
75	Waukesha silt loam	4,121	5,548	61,640	0	5,004
108	O'Neill loam	2,667	5,044	56,560	0	7,150
44	Bremer clay	4,472	5,716	91,264	1,256	Basic
146	O'Neill fine sand	3,057	2,156	10,688	472	Basic
105	Chariton silt loam	2,411	3,868	43,680	0	7,864
	SWAMP AND BOTTOMLAND SOILS					
72	Wabash clay	3,381	5,828	71,520	960	Basic
49	Wabash loam	4,499	5,912	69,984	4,216	Basic
91	Sarpy loam	3,569	6,080	56,516	14,844	Basic
111	Lamoure silty clay loam	2,694	9,416	92,572	6,188	Basic
144	Sarpy silty clay loam	3,461	6,416	72,984	17,736	Basic
28	Sarpy very fine sandy loam	4,256	2,044	16,120	39,640	Basic
48	Wabash silty clay loam	4,512	5,464	65,360	0	3,574
26	Wabash silt loam	4,984	7,928	49,460	0	6,434
89	Sarpy silt loam	2,882	4,008	38,292	548	Basic
62	Wabash fine sandy loam	4,916	5,352	57,068	5,292	Basic
102	Sarpy fine sandy loam	2,249	2,380	27,348	452	Basic

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

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

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	3,522	4,190	35,520	0	4,747
56	Webster clay loam	3,044	2,772	49,267	10,620	Basic
107	Webster silty clay loam	2,748	3,738	54,498	12,282	Basic
4	Carrington fine sandy loam	2,990	2,436	98,760	0	9,652
136	Lindley fine sandy loam	3,980	2,940	27,924	18,036	Basic
79	Shelby loam	5,192	2,310	19,920	37,080	Basic
	LOESS SOILS					
120	Tama silt loam	4,647	5,214	46,500	0	4,290
143	Tama silt loam (shallow phase)	4,626	3,276	23,280	0	14,242
80	Clinton silt loam	5,233	3,612	30,600	0	4,290
145	Tama loamy fine sand	2,444	1,932	16,572	828	Basic
	TERRACE SOILS					
60	Waukesha loam	4,647	3,570	43,980	0	8,580
43	Bremer silty clay loam	5,212	5,298	66,300	0	9,653
110	O'Neill fine sandy loam	3,354	4,416	50,940	0	4,290
88	Bremer silt loam	5,475	6,348	91,380	0	11,796
12	Bremer loam	3,677	3,570	70,020	1,080	Basic
45	Buckner fine sandy loam	2,889	2,772	25,740	0	3,517
75	Waukesha silt loam	6,344	3,996	45,120	0	6,435
108	*O'Neill loam					
44	Bremer clay	5,475	4,500	75,843	1,677	Basic
146	O'Neill fine sand	5,354	1,890	8,172	768	Basic
105	Chariton silt loam	3,596	5,004	25,400	0	9,652
	SWAMP AND BOTTOMLAND SOILS					
72	Wabash clay	5,778	5,088	74,904	1,356	Basic
49	Wabash loam	6,445	5,046	53,796	1,944	Basic
91	Sarpy loam	4,203	6,684	70,002	26,718	Basic
111	Lamoure silty clay loam	4,162	4,542	64,554	2,946	Basic
144	Sarpy silty clay loam	5,233	9,540	104,142	25,218	Basic
28	Sarpy very fine sandy loam	6,283	2,646	19,092	62,388	Basic
48	Wabash silty clay loam	5,879	4,962	66,960	0	4,290
26	Wabash silt loam	8,546	6,600	96,960	0	5,362
89	Sarpy silt loam	4,465	3,696	31,868	8,412	Basic
62	Wabash fine sandy loam	8,728	7,692	81,324	7,956	Basic
102	Sarpy fine sandy loam	3,435	2,142	20,490	7,470	Basic

*Not analyzed.

The needs of the soils of the county which have been evidenced from the analyses of the surface soils are apparently borne out by the analyses of the lower soil layers. In several cases the lower soil layers are not acid where the surface soil is acid, but in only one of these cases, however, is the actual amount of lime present sufficient to influence to any extent the lime content of the surface soil. Lime rarely moves upward in the soil in any case and hence it may be concluded that the test of the surface soils shows definitely the needs of the soils of this county.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Polk county to learn something of their fertilizer needs and of the value of applications of certain fertilizing materials. These experiments were carried out on the Carrington loam and the Webster clay loam, the two major soil types in the county. In addition, the results of an experiment on the Tama silt loam from Marshall

TABLE VII. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, POLK COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	5.50	27.21
2	Manure	11.50	40.82
3	Manure+lime	11.50	48.89
4	Manure+lime+rock phosphate	13.00	52.16
5	Manure+lime+acid phosphate	13.50	56.69
6	Manure+lime+complete commercial fertilizer	15.50	56.69

county are included in this report, inasmuch as this is a rather important type in the southern part of Polk county and the results should be applicable to Polk county conditions.

The arrangement of all the experiments was the same and consisted in the application of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. The amounts of these various materials applied were the same as are used in the field experiments, and hence the results of these greenhouse tests may be considered to indicate quite definitely what would be expected in the field. Manure was applied at the rate of eight tons per acre. Lime was added in sufficient amounts to neutralize the acidity of the soil as indicated by the Veitch test and to supply two tons additional. Rock phosphate was added at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of a complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in all the experiments, the clover being seeded about one month after the wheat was up. The results of the experiment on the Carrington loam from Polk county are given in table VII, the figures being the averages of the yields on the duplicate pots.

The effect of the manure showed up very definitely on both the wheat and clover crops, as it has many times in farm experience and there is no question

Fig. 3 Greenhouse experiment, wheat and clover on Carrington loam, Polk County.

Fig. 4 Clover on Carrington loam, Polk county.

but that this material is of large value on the Carrington loam in Polk county. The application of lime along with manure had no effect on the wheat crop, but it did bring about a distinct increase in the clover. It is not ordinarily expected that lime will have any large influence on the growth of small grains, but its use is well warranted by its influence on the legume in the rotation. The application of rock phosphate along with manure and lime increased the growth of both the wheat and the clover, the effect being particularly noticeable in the case of the latter crop. Acid phosphate gave an increase very similar to the rock phosphate in the case of the wheat but brought about a larger effect on the clover. The complete commercial fertilizer, on the other hand, showed a larger effect on the wheat but the same influence on the clover as did the acid phosphate.

It is apparent from these results that manure is a particularly valuable fertilizer for the Carrington loam in this county; they confirm the results obtained on the same soil type in many other counties. As noted above, the results are also borne out by considerable field experience.

The use of lime in addition to manure is necessary on the Carrington loam if the best growth of legumes is to be secured, and it should be noted that there is a secondary effect of the lime on the grain crops in the rotation, a beneficial influence which results from a greater clover or other legume growth. The need of testing this soil for acidity is evidenced and the importance of applying the amount of lime shown to be necessary is emphasized. There is rather definite evidence of the value of phosphorus fertilizers on this soil, both for wheat and for clover. It is not possible to determine the relative value of rock phosphate and acid phosphate, however, from these results, altho it might perhaps seem that acid phosphate has somewhat more effect on the clover. The differences are too small for definite conclusions. The complete commercial fertilizer seems to be somewhat preferable for wheat but has no advantage on clover. Again, however, the results are not definite enough to warrant recommendations.

The second greenhouse experiment was on the Webster clay loam from Polk county. The results of the experiment are given in table VIII.

TABLE VIII. GREENHOUSE EXPERIMENT, WEBSTER CLAY LOAM, POLK COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	14.25	68.04
2	Manure	20.25	81.64
3	Manure+lime	20.50	86.18
4	Manure+lime+rock phosphate	21.00	90.72
5	Manure+lime+acid phosphate	23.00	90.72
6	Manure+lime+complete commercial fertilizer	20.50	90.72

Manure apparently exerts a beneficial effect on the growth of wheat and clover on the Webster clay loam, considerable increases in crop yields being obtained with both these crops. This effect of manure is rather surprising on this soil type, as it is apparently well supplied with organic matter and it would not be expected that large effects would be evidenced by the use of manure. It may be that in this case the manure stimulates the production of available plant food to such a large extent that crops are benefited. The use of lime in addition to manure had no effect on the wheat and a slight effect on the clover. This particular soil type is usually not acid in the surface soil and not in need of lime. The sample used in this experiment was slightly acid and the addition of lime proved of value on the clover crop. The application of the phosphorus fertilizers gave slight increases in the wheat and also in the clover. The acid phosphate seemed to be somewhat more beneficial in the case of the wheat but all the materials used showed similar results in the case of the clover. Complete commercial fertilizer showed less effect than the phosphorus carriers in the case of the

Fig. 5 Wheat and clover on Webster clay loam, Polk county greenhouse experiment.

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

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	19.75	45.36
2	Manure	23.00	45.36
3	Manure+lime	23.50	49.89
4	Manure+lime+rock phosphate	24.00	54.43
5	Manure+lime+acid phosphate	27.50	72.63
6	Manure+lime+complete commercial fertilizer	24.00	63.50

wheat and gave the same results on the clover. These results indicate that manure is a valuable material for use on this soil and moderate applications should be made in order to stimulate plant food production and thus increase crop growth. Lime should be applied to the soil wherever it shows an acid reaction. There is evidence of value from the use of phosphorus fertilizers and tests should be carried out to determine the relative value of acid phosphate and rock phosphate on the individual farm. The complete commercial fertilizer showed less effect than the phosphorus carriers and it would seem that the latter would probably prove of more value on this soil type than any complete brands.

The results from the greenhouse experiment on the Tama silt loam in Marshall county are given in table IX.

The application of manure to this soil proved distinctly beneficial to the wheat crop but had apparently no effect on the clover. The use of lime in addition to manure gave no influence on the wheat but brought about a distinct gain in the growth of clover. The addition of phosphate fertilizers proved beneficial on both crops, the acid phosphate showing up very much better than the rock in both cases. The clover crop was increased to a very large extent by the use of this material. The complete commercial fertilizer had no advantage over rock phosphate in the case of the wheat but showed up somewhat better on the clover. It had less effect, however, on the clover than did the acid phosphate. It seems apparent from these results that manure is a valuable fertilizing material for use on this soil type and this material should be used wherever available for building up the fertility of the soil. Lime should be applied to the soil in proper amounts, which may be determined by tests, if the best growth of legumes is to be secured. Applications of phosphorus fertilizers are apparently of value and there is evidence of a larger effect from the use of acid phosphate than from the use of rock. These results should not be considered conclusive, however, and field tests must be carried out to determine definitely the relative merits of these two materials. Complete commercial fertilizers do not have any particular advantage over phosphorus carriers on this soil and indeed actually give smaller effects. Hence they cannot be recommended for use on this soil at the present time.

FIELD EXPERIMENTS

The field experiments which are under way in Polk county have not yet been carried on long enough to permit of conclusions from the results secured. However, some experiments have been under way for several years on the Agronomy

Farm at Ames in Story county on the Carrington loam, which is the most extensive soil type in Polk county. The results of these experiments are not entirely conclusive as yet and it is intended that they shall be carried on for a much longer period before definite conclusions are drawn. There are indications from some of the experiments, however, of the value of various fertilizing materials and hence the results of one of these experiments are given in this section of the report.

One of the experiments on the Agronomy Farm at Ames on the Carrington loam is arranged in five series of plots and on these plots there is practiced a five-year rotation consisting of corn, oats, clover, wheat and five years of alfalfa, the four-year rotation of corn, oats, clover, wheat being repeated five times and then the land left in alfalfa for five years on each series of plots. These experiments were started in 1915, but the yields that year and in 1916 are not included in the averages owing to the fact that they were undoubtedly abnormal and the effects of treatment did not show up satisfactorily until the third year of the experiment. The entire series of plots in this five-year rotation experiment includes tests with manure and with crop residues, representing the livestock system of farming and the grain system of farming. Only the manure plots are discussed here, as the crop residue plots have not yet given results of definite value. The treatments on these plots consist of application of manure, lime, rock phosphate and acid phosphate. The application of manure is made at the rate of eight tons per acre once in four years, rock phosphate at the rate of 2,000 pounds per acre once in four years and acid phosphate at the rate of 200 pounds annually. Lime is used in sufficient amounts to neutralize the acidity of the soil and supply two tons additional.

The yields secured of the various crops grown in this five-year rotation during the years 1917, 1918, 1919, 1920 and 1921, are given in table X. During these five years there were grown on the five series of plots, five crops of corn, six of oats, three of wheat, five of alfalfa, three of clover, one of barley and two of soybeans. The soybean crops were used when clover failed and the barley was grown when the wheat crop failed. The results given in the table are the averages of all the crops grown during the five years, the checks being the average of duplicate checks in each series of plots.

Examining the results given in this table, it will be noted that the addition of manure in this five-year rotation increased to a large extent the yields of all the crops grown in the rotation. The effect of the manure was particularly noticeable on the corn and clover of the rotation. Apparently the Carrington loam

TABLE X. FIELD EXPERIMENT, CARRINGTON LOAM, STORY COUNTY, AMES FIELD

Treatment	Corn bu. per acre 5 crops	Oats bu. per acre 6 crops	Wheat bu. per acre 3 crops	Alfalfa tons per acre 5 crops	Clover tons per acre 3 crops	Barley bu. per acre 1 crop	Soybeans tons per acre 2 crops
Check	53.5	49.6	17.9	1.16	1.70	11.0	2.12
Manure	67.8	56.4	24.3	1.26	2.62	12.2	2.56
Manure+lime	67.7	59.8	26.6	1.43	2.81	17.1	2.26
Manure+lime+rock phosphate	72.2	61.6	27.4	1.58	2.95	19.4	2.59
Manure+lime+acid phosphate	70.3	62.7	33.3	1.75	3.40	17.8	2.50

in this rotation will respond very profitably to applications of farm manure and it is evidently a very important fertilizing material for use on this soil type. Farmers are urged to carefully preserve and apply all the manure produced on their farms and they may thus increase their crop yields and aid in keeping their soils fertile.

The use of lime in addition to manure brought about small increases in the oats and wheat crops but exerted a pronounced effect on the alfalfa and clover. The results obtained with the soybeans were evidently somewhat abnormal, but as the results are the averages of only two crops of soybeans, the decrease noted in the table should not be considered of significance. It would be expected that lime would show the greatest effect on the legumes of the rotation and this expectation is borne out by the results secured. It is interesting to note, however, that the oats, wheat and barley were all increased to a considerable extent by this material.

The application of phosphate fertilizers is apparently of some value on the Carrington loam, both the rock phosphate and the acid phosphate giving increases in yields, many of them being very considerable. There seems to be a considerable difference in the effect of these two materials on the different crops of the rotation. For example, the acid phosphate shows up to very much better advantage on the wheat than does the rock phosphate and similarly in the case of the clover the effect of the acid phosphate is very much more pronounced. With the corn and oats, however, there is very little difference between the two materials. With the alfalfa, acid phosphate seems to have a somewhat greater effect. It seems evident from these results that the application of phosphorus fertilizers may be of considerable value on the Carrington loam in Polk county at the present time. Definite recommendations regarding the use of phosphorus or regarding which phosphate fertilizer should be employed cannot be given from the data at present available. It seems safe to say, however, that phosphorus fertilizers will probably prove of value and farmers are urged to test the use of both rock phosphate and acid phosphate in the effort to determine which will be of the most value under their particular soil conditions.

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

Field experiments are now under way in Polk county and in the course of the next few years results will be available to indicate the fertilizing materials which may be used with profit in this county. For the present, the suggestions regarding treatments which will be made here are based on the laboratory and greenhouse tests and on the field tests in other counties. They are also based, however, on much field experience, and no recommendations are made which have not been proven to be of value by practical experience. Where definite data on the effects of various materials are not available, as in the case of phosphorus, recommendations are made that tests be carried out on individual farms. When farmers test the use of these materials under their own conditions, they may then secure first hand knowledge of their value and until the field experiments now

under way are completed, this is the only definite recommendation which can be made regarding the use of phosphorus fertilizers. The suggestions made in the following pages should be understood to be of proven value and any of them may be put into operation under general farm conditions.

MANURING

The soils of Polk county are not strikingly deficient in organic matter content except in a few instances, but neither are they very well supplied and additions of farm manure would be of considerable value on practically all of the types in the county. Only in the case of the Webster silty clay loam is there any extremely large amount of organic matter present, and even in this case the addition of a small amount of manure to stimulate the production of available plant food would be of value in increasing crop yields. The experiments reported in the preceding pages and the experience of many farmers gives very definite support to the statement that manure is a most valuable fertilizer for use on the soils of the county. It always brings large increases in crop yields and in most cases the addition of other fertilizers would not be of value unless manure were also applied. On sandy soils, and especially where truck crops are grown, the addition of manure is particularly valuable and in some instances absolutely necessary for the best growth of crops. In all cases, however, the value of the crop increases secured by the use of manure is sufficient so that liberal applications of this material should be strongly advocated. Every farmer in the county should see to it that the manure produced on his farm is carefully preserved and returned to the soil if he would secure the best crop yields and keep his soils permanently fertile.

Manure exerts a beneficial effect on soils because of its chemical, physical and bacteriological effects. It contains considerable amounts of plant food constituents which have been removed from the soil by the crops grown and by its use, therefore, the life of the soil is lengthened or in other words, the time is extended before any plant food constituent becomes actually lacking. It improves the physical condition both in heavy clay soils and in light sandy soils. It makes the latter more retentive of moisture, less open and porous and less subject to losses of the valuable constituents by leaching. It opens up heavy soils and makes them better aerated, less impervious, and less retentive of moisture. This means that there will be a greater production of available plant food, as well as better general conditions for the growth of crops. Large numbers of bacteria are contained in manure and these play an important part in making plant food available. The organic matter which manure contains has an important effect, not only on the physical conditions of the soil but also upon the bacterial growth and activities. The organic matter serves as food for bacteria and stimulates their development and this means a further increase in available plant food production. It is quite probable that the bacterial effects of manure are of especial significance on heavy, newly-drained soils which are high in organic matter. Under such conditions the stimulation of available plant food production is particularly necessary and the beneficial effect of manure on such types as the Webster clay loam, silty clay loam and the Bremer soils is undoubtedly due mainly to improved bacterial conditions. In general, however, the beneficial

effect of manure may not be attributed to any one influence, but is probably due to physical, chemical, and bacterial effects combined.

When compared with commercial fertilizers, it would seem that the application of manure is a very simple and inexpensive operation and the farmer who does not carefully preserve and utilize all the manure produced on his farm is wasting one of his most valuable natural assets. It is difficult to understand why greater care is not taken of this material in order to secure the largest possible effects from its use. In spite of all that has been said about the storage of manure, very frequently it is stored without any care whatever to prevent losses by leaching and weathering, perhaps on a hillside with a slope running down to a stream and the soluble portion of the manure washing away from the farm in large amounts after every rain. Under such conditions the manure will lose 70 to 90 percent of its value and the effect when applied to the soils will be reduced to just the same extent. The farmer may consider manure a waste product to be disposed of with the least possible difficulty, but if he does not prevent losses of valuable portions before applying it to his soils his income from his crops will be reduced in proportion to the decreased value of the manure.

There are many ways in which manure may be stored to prevent losses. A covered yard or a pit may be provided. It may be composted. No one method can be suggested to fit all conditions and in general it may be said that almost any method will be satisfactory provided the manure is kept moist and compact and not exposed to the weather. It may be possible in some instances to apply manure to the soil as produced and thus eliminate the necessity of storage. When this practice can be followed the largest possible effect of the manure is secured on the crop growth, but it is not always practicable to follow this method and in most cases it is necessary to store the manure. If proper care is taken in storing, quite as satisfactory results may be secured from its use as if it were applied directly. It has been estimated that 75 to 80 percent of the plant food removed from the soil by the crops grown may be returned to the land by the use of well preserved manure. If the farmer will care for and utilize manure to the best advantage, he may keep his soils in the best condition of fertility for a long period of years.

The usual application of manure is 8 to 10 tons per acre once in a four-year rotation. In some cases larger applications are made to certain soils, particularly sandy types or for the growth of truck crops. It is not advisable, however, to apply more than 16 to 20 tons per acre for general farm crops. Only for truck crops will larger amounts than this prove profitable. Unfortunately the production of manure on the average livestock farm is not sufficient to permit of large applications to all the soils of the farm and this means that some fields are left without additions of manure. Hence on many farms all the soils cannot be kept up in organic matter by the use of manure and some other material must be utilized. On the grain farm very little manure is produced and here some substitute for farm manure must be employed.

Green manuring is a practice which may be followed as a supplement or substitute for manuring. Leguminous crops are considered the most desirable for use as green manures inasmuch as they are able, when well inoculated, to take

up nitrogen from the atmosphere and fix it in the soil for the use of subsequent crops. They act, therefore, as a nitrogenous fertilizer while at the same time they keep up the supply of organic matter on both the grain farm and also on the livestock farm. Non-legumes are often used as green manures and in some cases may be of considerable value in that they add to the organic matter content of the soil. They do not add nitrogen, however, and hence they have less value than legumes. When the organic matter content of the soil is low, nitrogen is also low and hence in practically all cases leguminous crops are particularly desirable for use as green manures.

Many legumes are available for use under a wide variety of conditions and it is possible to choose some one legume which will fit in with almost any rotation. Green manuring is a practice, therefore, which may be followed on some livestock farms and must be practiced on grain farms if the supply of organic matter and nitrogen is to be kept up. On the lighter soils in Polk county, and particularly those which show evidence of lack of organic matter by a light color, green manuring may be practiced with profit. It should not be practiced blindly or carelessly, however, for it may bring about undesirable effects if not carried out properly. Advice regarding green manuring under special soil conditions will be given by the Soils Section upon request.

The utilization of crop residues, such as straw and stover, is a third means by which the organic matter content of the soil may be kept up. Too often these materials are burned or otherwise destroyed and there is a loss of much valuable organic matter. Such a practice means that the farmer is throwing away material which is of considerable aid in keeping his soils productive. Crop residues may be used for feed or bedding on the livestock farm and returned to the soil with the manure. On the grain farm they may be stored and permitted to decompose partially before application or they may be applied directly. It is particularly important on the grain farm that all residues be returned to the soil but they are also of importance under livestock farming conditions. Crop residues are of value because of their organic matter content and because of their content of plant food constituents. They often increase crop yields to a considerable extent and they constitute a valuable supplement to farm manure and green manures.

THE USE OF COMMERCIAL FERTILIZERS

The soils of Polk county, according to the analyses given earlier in this report, are not very well supplied with phosphorus and, in fact, with one or two exceptions, the supply is rather low. There is no question, therefore, but that phosphorus fertilizers will be needed on the soils of this county in the near future. They would probably be of use, however, in many cases at the present time. The greenhouse experiments which have been reported here and the field experiments in other counties indicate the possibility of value from the application of phosphorus to certain of the major soil types in the county. The field experiments which are now under way in this county will permit of definite conclusions along this line after results have been secured over a period of years. For the present, the only recommendation which can be made is that phosphorus be tested under actual field conditions. Even tho the supply in the soil is sufficient to take care

of the needs of many crops, there is no assurance that the amount of available phosphorus is sufficient for even one crop. The figures given in the analytical tables in this report show the total phosphorus content of the soils but do not give any indication of the amount which is available. There is no satisfactory method of determining the occurrence of available phosphorus except by testing in the field. It is well known, however, that where the total supply is as low as it is in this county, there is danger of a deficiency in available phosphorus. All the phosphorus which is utilized by plants must be in a soluble available form and even if there is a large total supply, crops may suffer for a lack of phosphorus if the production of the plant food in an available form is too slow. It is quite probable, therefore, that phosphorus fertilizers might yield profitable returns on the soils of this county at the present time and particularly so if the phosphorus which they contain is not being made available as rapidly as it should be.

There are two important phosphorus fertilizers on the market and one of these must generally be selected for use on Iowa soils. The two materials are rock phosphate and acid phosphate. The former is insoluble and must be changed into an available form before it can be of use to plants. The latter is a soluble phosphate and the element is present in it in a form directly utilizable by crops. Acid phosphate, however, costs considerably more than rock phosphate and it contains less phosphorus. It is impossible at the present time to say which of these materials should be used under the different soil conditions existing in Polk county. Field experiments now under way in the county are comparing the value of these two sources of phosphorus. At the present time it is urged that the two materials be tested under actual farm conditions and their relative economic value determined. The material which yields the largest influence at the lowest cost should be considered the most economic material for use. Farmers may test these materials on small areas with little difficulty. Directions for the carrying out of such tests are given in Circular 51 of the Iowa Agricultural Experiment Station and advice along this line may be secured from the Soils Section upon request.

The nitrogen content of the soils of Polk county in some cases is very low while in others the amount of this element is considerable. Only in few cases, however, is there any extremely large supply. In practically all instances, the amount of nitrogen is insufficient to take care of the needs of crops for any extended period of years. It is quite evident that this element must be considered in any system of permanent fertility planned for the soils of the county. The application of farm manures and the return of all crop residues will aid considerably in keeping up the nitrogen content, but they are not sufficient, as has been indicated in a previous section of this report, and the supply of nitrogen will gradually decrease, due to utilization by crops and leaching, if some other means of supplying nitrogen to the soil are not employed.

The utilization of well inoculated legumes as green manures is a most desirable practice for adding nitrogen to soils. Such materials are the cheapest nitrogenous fertilizers which can be used and they have a double value in that they not only supply nitrogen but they also add large amounts of organic matter to the soil. Every rotation should contain a legume and it is very important

that the legume be thoroly inoculated, as only in this way can the nitrogen of the atmosphere be utilized. The handling of the legume is very important if the soil is to benefit to the largest extent from its growth. A large portion of the crop must be turned under in the soil if its nitrogen content is to be increased materially. If the entire legume crop is harvested for hay, there will be practically no increase in nitrogen content in the soil. If only a part of the crop is harvested and removed and the remainder is turned under in the soil, there may be considerable nitrogen added. If the seed crop only of the legume is removed and the remainder of the crop plowed under, a large amount of nitrogen may be supplied to the soil. The greatest effects, however, are of course secured when the entire legume crop is turned under. The amount of nitrogen added to the soil will depend in this case upon the size of the crop and the efficiency of the inoculation. By the proper growing and handling of legume crops in the rotation, therefore, the nitrogen content of the soils of this county may be built up and kept up. Commercial nitrogenous fertilizers are very expensive and they will not be needed if legumes are utilized according to the plan suggested. Small applications of commercial materials may be used as top dressings to encourage the early growth of certain crops, particularly truck crops, but their use on the soils of this county for general farm crops cannot be recommended. It is highly improbable that they would prove economically profitable. If they are tested on small areas, however, and economic returns are secured, there is no objection to their use.

Analyses made of many of the soils of the state have shown a large supply of potassium and it is very unlikely that this element will be needed on the soils of Polk county for many years to come. The total amount present is so large that there should be no difficulty in securing a proper amount of available potassium to keep crops supplied. If soils are well drained and cultivated and abundantly supplied with organic matter, the production of available potassium should be sufficient in most of the soils of this county for satisfactory crop yields. It is hardly likely, therefore, that potassium fertilizers would prove profitable for use in this county for general farm crops. Small applications as top dressings might be desirable in some cases in order to stimulate early growth. Such materials might be used economically in truck crop growing. There is no objection to the use of potassium fertilizers if they prove profitable, however, and if they are tested on small areas and crop increases secured will warrant their application, they may be applied without injuring the soil.

The use of complete commercial fertilizers is not considered necessary on the soils of this county at the present time. They may be used in truck crop growing and on gardens and prove distinctly profitable, but for general farm crops it is believed that phosphorus fertilizers will prove more profitable. These materials are being tested in the field experiments now under way in the county and the effect on crops from their use is being compared with the effect of various phosphorus fertilizers. Definite comparative data along this line will be available in the future but the indications at present are that the complete brands are less desirable than the phosphorus carriers. If farmers are interested they may readily test any complete fertilizer on a small area on their own farms and determine whether or not the material is profitable for use. It is urged, how-

ever, that such materials should always be tested in comparison with phosphate fertilizers in order to get an accurate idea of their value and to determine whether phosphorus fertilizers would not prove quite as desirable. There is no objection to the use of complete commercial fertilizers if they prove profitable and particularly if they show greater returns than phosphorus carriers.

LIMING

Many of the surface soils of Polk county are very well supplied with lime and are not in need of applications of this material at the present time. There are a number of types, however, that give an acid reaction and on these types lime should be applied. The Carrington and Shelby soils of the drift uplands and the Tama and Clinton soils of the loessial uplands are all acid. Practically all of the terrace types show acidity, but the bottomland soils are very largely high in lime content, and the Webster soils of the upland are well supplied at present. The lower soil layers are very little different in reaction than the surface soils. Those types which are basic at the surface are basic in the subsoil and the supply of inorganic carbon generally increases in the lower layers. In a few cases where the surface soils are acid, the subsurface and subsoils show a basic reaction but in none of these instances is the supply of inorganic carbon sufficient but that lime will need to be applied in the near future. Hence the indications of lime needs which are given in the surface soils are borne out by the data on the lower soil layers. The figures in the tables given earlier in this report are merely indicative of the needs of these soil types and applications of lime should not be based upon them but upon actual tests on the individual soil. Average figures, even if these figures are the result of many analyses, will not show the exact needs of a soil.

The application of lime to acid soils exerts a beneficial effect on them due to a stimulation of bacterial action and an increase in available plant food production, as well as to the removal of injurious acidity and to a supplying of plant food. Hence the use of lime may bring about increases in crops which are not ordinarily sensitive to acidity. Such increases may be due to the production of more available plant food. Furthermore, if the legume in the rotation is increased in growth by the use of lime, the succeeding crops will be benefited indirectly because of the greater amount of organic matter returned to the soil and because of the addition of nitrogen. This may be considered an indirect effect from the use of lime. It is generally conceded, however, that all crops make their best growth on soils which are not acid and hence it is very desirable that soils be tested for acidity and that lime be applied as needed. It is a profitable practice even if only the legume crop of the rotation is considered but when the other crops are increased also, the value of lime is very great.

The farmers of Polk county should test their soils and determine the lime needs. They may do this themselves or they may send samples to the Soils Section of the Iowa Agricultural Experiment Station and have them tested free of charge. Furthermore, they should see to it that their soils are tested regularly at least once in a four-year rotation. One application of lime to a soil is not sufficient, as lime is removed from soils continually thru leaching and utilization by crops. The most desirable practice is to test the soil before the clover

crop or other legume of the rotation is seeded and apply the necessary lime preceding that crop. The largest effect from the use of the material will be secured in this way and satisfactory growth will be secured. Further information regarding the use of lime and sources from which the material may be secured are given in Bulletin 151 and Circular 58 of the Iowa Agricultural Experiment Station.

THE ROTATION OF CROPS

The natural fertility of soils is gradually reduced thru the growth of crops but the reduction is much more rapid where any one crop is grown continuously. Not only is the fertility of the soil decreased, but the actual income from the land and the value of the land is reduced. It has often been believed that the growing of a certain crop continuously would provide a larger income from the land than the use of a rotation containing crops of less money value. This assumption is incorrect, however, even if the crop grown continuously has a higher market value than the other crops used in the rotation. The value of all the crops grown over a period of years will be greater where a rotation is followed.

No rotation experiments have been carried out in Polk county, but there are several rotations which have been followed in the county and in other parts of the state with satisfactory results. These rotations are suggested below and any of them may be used in this county. Variations in these rotations may be made as desirable and in fact almost any rotation may be employed provided it contains a legume and the most profitable crops.

I. FOUR OR FIVE-YEAR ROTATION

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

II. FOUR-YEAR ROTATION WITH ALFALFA

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

III. THREE-YEAR ROTATION

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

DRAINAGE

The natural drainage system of Polk county is fairly adequate, but there are considerable areas in the central portion of the county between the Skunk river and the Des Moines river where drainage is poor and the installation of tile is very necessary for the most satisfactory crop production. There are also small areas in the western part of the county near Grimes where tiling is very desirable. These areas are mapped as Webster clay loam and Webster silty clay loam and it may be said that in general where these types occur, drainage is poor.

There are smaller areas of terrace and bottomland types which are likewise poorly drained. The soils of the Bremer series of the Wabash and Lamoure series are all in need of drainage. In the case of the Wabash and Lamoure types, as they are on the bottoms, they are of course subject to overflow and are not only in need of drainage, but of protection from overflow.

In general it may be said that the Webster and Bremer soils of the county are chiefly in need of drainage in order to make them satisfactorily productive. No other treatment will prove of value on these soil types until they are adequately tiled out and when this is done very satisfactory crop yields may be secured, as the soils are naturally highly productive. The installation of tile may be rather expensive, but the returns secured more than warrant the outlay. The experience of many farmers confirms this conclusion and proves that proper drainage may mean the difference between very satisfactory crops and no crop at all.

THE PREVENTION OF EROSION

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

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

Light, open soils which absorb water readily are not likely to be subject to erosion, while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion, while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

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

In Polk county erosion occurs to a considerable extent in the areas of Lindley fine sandy loam, Shelby loam and Clinton silt loam. In some instances serious washing has occurred in some of the other soil types, particularly the Carrington loam and the Tama silt loam, and wherever any removal of surface soil thru this destructive action occurs, some means of control should be adopted.

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

EROSION DUE TO DEAD FURROWS

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

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

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

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

SMALL GULLIES

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

Checking Overfalls. The formation of small gullies or ditches is practically always the result of overfalls and one of the most important problems is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is very desirable before any success can be had in filling small or large gullies.

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

The modification of this system of staking in which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of four to ten feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed up stream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend of course upon the size of the gully. These posts should be set well into the ground and spaced about four feet apart, being arranged in a V-shape with the point down stream and lower in the center than at the sides of the ditch. This modification of the staking in method is proving very satisfactory.

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

The Earth Dam. The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It

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

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

The Adams Dam. This dam is practically the same as the Christopher or Dickey Dam. In fact the principle of construction is identical. In some sections the name "Adams dam" has been applied and hence it is mentioned separately. This is one of the most satisfactory methods of filling gullies and the dam may also serve as a bridge. The installation of a culvert is generally made of sewer tile with tightly cemented joints and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an up-stream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially the larger gullies.

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

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

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

erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

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

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

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

LARGE GULLIES

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

BOTTOMLANDS

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

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

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

HILLSIDE EROSION

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

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

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

Contour Discing. Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proven quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first, as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

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

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

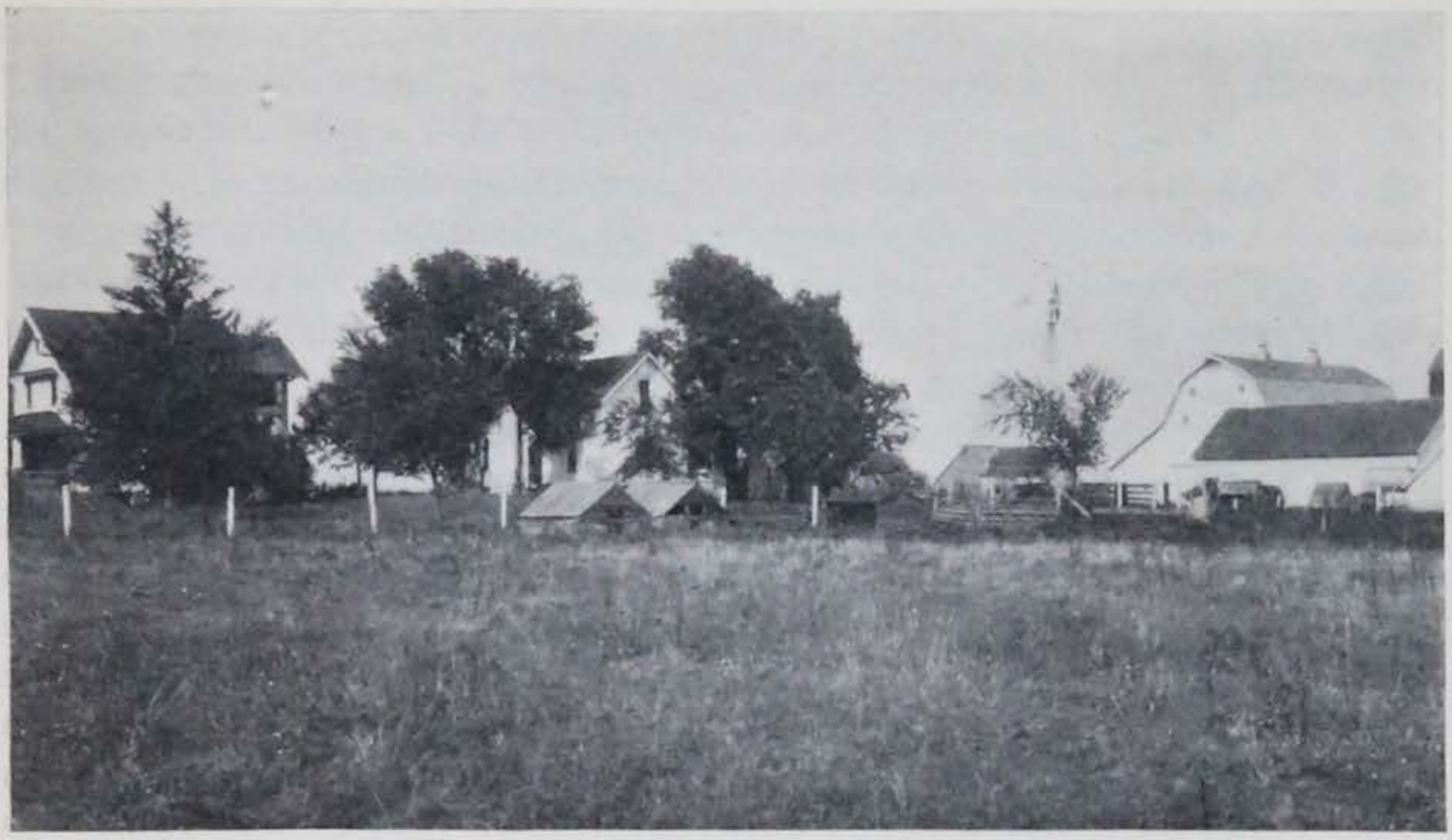

Fig. 6 A Polk county farmstead on Carrington loam.

thereby reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

INDIVIDUAL SOIL TYPES IN POLK COUNTY*

There are 31 soil types in Polk county, a shallow phase of the Carrington loam, a shallow phase of the Tama silt loam and areas of riverwash and muck and peat, making a total of 35 separate soil areas. They are divided into four large groups according to their origin and location and these groups are known as drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are six drift soils in the county belonging in the Carrington, Webster, Lindley and Shelby series and these, with the shallow phase of the Carrington loam, make seven soil areas. The area covered by this group of soils amounts to 60.1 percent of the total area of the county.

CARRINGTON LOAM (1)

The Carrington loam is the most extensive drift soil in the county and it is the largest individual type. Together with the shallow phase, which is minor in area, it covers 32.9 percent of the total area of the county. It occurs chiefly along the drainageways of the county, altho there are many smaller bodies of it occurring on the uplands of the flatter regions. The largest continuous area broken only by narrow strips of bottomland extends across the county from Mitchellville thru Des Moines to the western boundary of the county. This area marks the edge of the drift soils of the county, the area to the south

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

being covered by loess types. Rather considerable areas of Carrington are found south of the Des Moines river around Grimes, and in the northeastern part of the county on the uplands between Indian creek and Skunk river. The type is also developed to some extent in the northwestern part of the county along Big creek. There are numerous small areas in all parts of the county north of Des Moines but in general the areas mentioned are the most important.

The surface soil of the Carrington loam is a dark brown mellow loam extending to a depth of 12 inches. At that point the soil becomes a brown to dark yellowish-brown heavy loam. At 18 to 20 inches the subsoil is encountered and this is a yellowish-brown to brownish-yellow somewhat gritty silty clay loam to clay. Occasionally boulders occur on the surface and thruout the soil section and glacial pebbles are not uncommon. The surface soil of the type along the east county line near Farrar, along the west county line near Granger (in Dallas county) and near Campbell is shallower than typical, averaging 8 to 10 inches and the organic matter content is lower, the color somewhat lighter and the sand content higher. In these areas the texture is almost a fine sandy loam. There are small areas on the sharper slopes which have a grayish cast in the lower subsoil and contain a small amount of lime. These areas occur mainly in the territory adjoining the loess soils in the southern part of the county. These small areas really belong in the Clarion series but owing to their small extent they have not been separated out in the county. In the northern part of the county on some of the smaller knolls, the subsoil of the type occasionally becomes quite sandy. When adjoining the Webster series, the surface soil of the type seems to be somewhat higher in organic matter supply and clay content, but the line of division between the Carrington and Webster soils is usually rather sharply defined. When the type is associated with silt loams and especially with the Tama silt loam, the surface soil is somewhat shallow and the subsoil is a reddish-brown gritty clay.

In topography the Carrington loam is strongly undulating to gently rolling and in general it is adequately drained. In some of the smaller flat areas in the central portion of the county where the type is associated with the Webster soils, artificial drainage has often proven of value.

Probably 80 percent of the Carrington loam in the county is under cultivation, some of the more rolling areas being kept in pasture. The forest growth which occurred in the more rolling territory was composed mainly of oak, ash, elm, hickory, locust, hackberry and wild cherry with undergrowth of hazel and buck brush. The original native grasses have been largely replaced by blue-grass on the pasture areas. In the cultivated portion corn is the most important crop grown and yields on the average 35 to 40 bushels per acre. Oats and wheat are of secondary importance, oats yielding 35 to 45 bushels, winter wheat 18 to 25 bushels and spring wheat 18 to 20 bushels. Winter wheat is grown more commonly than the spring varieties, altho the latter are increasing in favor. Clover and timothy are the most important hay crops and yields of 1½ to 1¾ tons per acre are secured. Clover alone is grown to some extent, yielding one to two tons per acre. Timothy alone is also grown somewhat, yielding one to 1½ tons per acre. Some native hay is cut on the more rolling areas. Alfalfa is produced successfully under favorable seasonal conditions and yields of 2½

to 3 tons per acre have been secured. In the southern part of the county apples, berries and grapes have been grown on this soil with good results. Some trucking is carried on in the vicinity of Des Moines. Sweet corn is produced to some extent for the canning factories and yields 2½ to 3 tons on the average. Pumpkins are grown quite extensively, producing at the rate of 3 tons per acre.

The needs of the Carrington loam for greater crop growth include the use of lime, the application of manure and probably also the addition of phosphorus fertilizers. The type is practically always acid in reaction and hence it should be tested and lime applied as shown to be necessary according to the tests, if the best growth of legumes and of farm crops in general is to be secured. The soils are not particularly well supplied with organic matter and applications of farm manure bring about large increases in crop growth. Where farm manure is not available or the amount is not sufficient to keep all the soils of the farm supplied, proper utilization of the legume crop of the rotation should be practiced in order to increase and maintain the organic matter and nitrogen content of the soil. Preliminary tests have indicated that phosphorus fertilizers may be of value on this type and while the results are not sufficiently complete at the present time to permit of definite conclusions, it is urged that phosphorus fertilizers be tested in the field on small areas and in this way the need of this element may be determined. Acid phosphate and rock phosphate may be employed in such tests and thus it will be possible to determine which of these materials will yield the most profitable returns. Complete commercial fertilizers are not recommended for use on this soil at the present time, altho there is no objection to their use if they prove of value. Tests of such materials should be made in comparison with phosphorus fertilizers, as it is generally believed that the latter materials will prove of more economic value than the complete brands. The type is usually very satisfactorily drained but in the few instances where drainage is poor, tiling could be practiced. There is very little erosion of this type except in a few areas where the topography is more steeply rolling than typical.

CARRINGTON LOAM—SHALLOW PHASE (142)

The shallow phase of the Carrington loam is of minor importance in the county, covering less than one percent of the total area. It occurs in small irregular shaped areas in various parts of the county, usually on the rolling slopes to the larger creek valleys. A few areas are found on the gentle slopes and near the heads of drainageways. The type is, of course, the result of erosion or the washing away of surface soil.

The surface soil of this shallow phase of the Carrington is usually about six inches in depth. It is lighter colored than the typical soil and the subsoil, which is frequently plowed up, is a brown to yellowish-brown silty clay loam, grading into a grayish-yellow silty clay loam in the lower depths and particularly on some of the steeper slopes. Boulders and pebbles are common in the subsoil. This soil differs from the Shelby loam in that it has a more compact subsoil and contains a smaller percentage of gravel.

Most of the soil is used for pasture, as it is too rolling for profitable cultivation, the topography being generally steeply rolling. On the pastured areas native

prairie grasses are found, with some forest trees, chiefly oak, elm, hickory and hazelnut. On the less rolling areas, the land is sometimes cultivated along with the surrounding soils but the yields of general farm crops are less satisfactory than on the typical Carrington.

The needs of this soil are first of all, for protection from washing or erosion and then for the addition of organic matter. There are some areas where the soil should undoubtedly be kept in permanent grass or pasture in order to prevent the excessive washing. Additions of farm manure and the growing and turning under of green manure crops would be very desirable where cultivated crops are to be grown. The soil is acid and in need of lime. It would probably also respond to phosphorus fertilizers.

WEBSTER CLAY LOAM (56)

The Webster clay loam is the second largest drift soil and the second largest type in the county, covering 17.0 percent of the total area. It occurs generally on the uplands in the flatter portions of the north three-fourths of the county. The largest areas of the type occur between the Skunk river and Four Mile creek and between Four Mile creek and the Des Moines river, from Mitchellville north thru Elkhart and from Oralabor north to Sheldahl. It is found generally on the gentle slopes and flatter uplands, with the Carrington loam separating it from the streams. Some areas occur, however, on long gentle slopes extending to the drainageways. It is associated very closely with the Webster silty clay loam, this type occurring in the lower flat areas which are particularly poorly drained. In the area northeast of the Skunk and in the southwestern part of the county, the type is found on the flat level upland areas.

The surface soil of the Webster clay loam is a very dark brown or nearly black clay loam 15 inches in depth. It is underlaid by a dark yellowish-brown rather compact clay loam which at about 24 inches becomes a yellowish-gray or grayish-yellow gritty clay loam or clay. Where the type joins lighter textured soils, the surface two to four inches may be quite loamy. Glacial boulders and gravel occur occasionally on the surface and thru the soil section. The lower subsoil is usually high in lime content and frequently the upper soil layers will contain lime. Reddish-brown iron stains are usually found in the subsoil of this type.

In topography the Webster clay loam is almost flat to very gently undulating and the drainage is poor. The installation of tile has been made in many areas and has proven very desirable for this type. In fact, when well drained, the soil is one of the most productive in the county. It is practically all under cultivation and the important crops grown are corn, oats, hay and wheat. Corn yields 40 to 50 bushels per acre and in favorable seasons yields may run very much higher. Oats yield 30 to 40 bushels per acre and winter wheat 18 to 23 bushels per acre. Little barley or spring wheat are grown. Timothy and clover mixed yield about two tons of hay per acre, red clover alone 1¾ to 2 tons and timothy alone 1¼ to 1¾ tons. Alfalfa is grown on small areas and satisfactory crops are secured. Near Altoona, Grimes and Maxwell, sweet corn and pumpkins are grown for the canning factories, average yields of the former amounting to three to five tons per acre and of the pumpkins, three tons per acre.

The Webster clay loam is a very productive soil and, when properly handled, very satisfactory crop yields may be secured. In the first place it should be thoroly drained by the installation of tile. When this is accomplished the soil must be properly cultivated. It should not be plowed when too wet, as it forms clods and becomes difficult to work down into a good tilth. In dry seasons it may bake and crack. Additions of small amounts of farm manure are quite desirable on this soil in spite of the fact that it is high in organic matter content. It is particularly desirable when the soil is newly drained, that an application of manure be made in order to stimulate the production of available plant food. If the surface soil is acid, lime should be applied in order to secure the best growth of legumes. In most cases, however, this material is not needed. The addition of phosphorus fertilizers may prove of value on this type and tests of acid phosphate and rock phosphate are recommended.

WEBSTER SILTY CLAY LOAM (107)

The Webster silty clay loam is the third largest drift soil in the county and the fourth largest soil type in the county, covering 4.4 percent of the total area. It occurs mainly thruout the central portion of the county between Skunk river and the Des Moines river in association with the Webster clay loam. The areas of this type are usually surrounded by the Webster clay loam. In some instances the type is associated with the Carrington loam, occupying narrow strips in the lowest portions of the depressions along sluggish drainageways or occurring as larger irregular areas, giving the appearance of having formerly been shallow ponds or marshes. The largest areas occur in the vicinity of Bondurant and northwest of Ankeny.

The surface soil of the Webster silty clay loam is very dark brown to nearly black in color and extends to a depth of about 18 inches. This is underlaid by a dark brown to dark drab clay which at about 24 inches grades into a yellowish-gray or grayish-yellow clay loam or clay. The subsoil shows many reddish-brown iron stains and contains numerous lime concretions. Both soil and subsoil are highly calcareous. In some of the lake-like depressions the surface soil to a depth of three to five inches may be quite peaty. Clay spots occur in the center of a few areas and where surrounded by the Carrington soils, the surface soil may be loamy in texture. This type is darker colored than the clay loam, contains more silt in the surface soil and occurs in more depressed areas. When wet it is very sticky but does not crack as badly as the clay loam, upon drying, owing to its higher content of organic matter. Strips of soil of this type occurring around small pond-like depressions frequently contain so-called "alkali salts" to such a large extent that crops are injured. Only small narrow areas of the type are affected in this way and frequently the alkali does not appear until after the area has been drained. The removal of the excess salts in such areas should be accomplished by the installation of tile thru the alkali spot and thru the liberal application of horse manure.

In topography the Webster silty clay loam is nearly level to depressed, and drainage is naturally very poor. Water may stand on the surface of undrained areas for long periods following heavy rains. The type must be thoroly ditched and tile drained in order to make it properly productive. Considerable areas

of this type have been kept in native grasses, especially in the larger areas and where water remains for long periods after rains. On such areas there is a large growth of slough grasses and bluegrass which are either used for pasturage or hay. A considerable portion of the soil is cultivated along with the clay loam and crop yields on properly drained areas frequently surpass those obtained on the clay loam. In wet seasons small grains are apt to lodge badly and cultivation is difficult.

This type is primarily in need of drainage to make it satisfactorily productive. When this is accomplished large crop yields will ordinarily be secured. It is high in organic matter and nitrogen and is not in need of lime. The phosphorus content is not high and this element may be needed in the near future. It is possible that applications of phosphorus fertilizers might prove of value in some cases now. Small applications of manure might be of use on newly drained areas, but should not be applied preceding the growth of small grains. Where alkali conditions occur in this type, proper installation of tile is the first operation needed and this should be followed by a liberal application of manure or by the turning under of a green crop, which will aid in the removal of the large amount of salts causing the alkali condition.

CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor type in the county covering 2.5 percent of the total area. It occurs chiefly on smooth and rather gradual slopes to the north of the Des Moines river and along the Skunk river, Indian creek, Big creek and Little Beaver creek. The largest continuous area occurs northeast of the Skunk river. Rather considerable areas are also found along the Des Moines river in the vicinity of Des Moines and in the area about Polk City.

The surface soil of the Carrington fine sandy loam is a dark brown to dark grayish-brown in color. At about 15 inches this passes into a brown to yellowish-brown fine sandy loam which sometimes changes to a loamy fine sand or fine sand in the lower part of the three foot section. In some areas the organic matter has been removed to a considerable extent and the surface soil is a grayish-brown in color when dry. When associated with the heavier soils, the surface soil may be quite loamy and the subsoil a heavy loam or light silty clay loam. Very few glacial boulders and little gravel is found.

In topography this type is rolling to steeply rolling, and it is well drained. In areas with the lighter textured subsoil, drainage may be excessive and crops may suffer during periods of drouth. About 60 percent of the soil is under cultivation, the remainder being used for pasture. Corn, oats and wheat are the principal crops grown. Near Des Moines watermelons, cantaloupes, sweet potatoes and other truck crops and small fruits are grown satisfactorily. Some of the areas are too steeply rolling to permit of satisfactory cultivation and these areas should undoubtedly be kept in permanent pasture.

This soil may give very satisfactory yields of general farm crops in seasons of normal rainfall. Frequently crop yields are quite as large as on the Carrington loam but dry weather usually reduces the yields considerably. The soil is low in organic matter and nitrogen and applications of farm manure are very desirable. Large amounts of this material should be used in order to make the

soil more productive and to reduce the danger of crop injury from drouth. The utilization of manure is especially important on the areas where truck crops are grown. In case farm manure is not available in sufficient amounts, leguminous crops should be utilized as green manures in order to build up the soil in organic matter and nitrogen. The soil is acid in reaction and should receive applications of lime in order to secure the best growth of legumes. The phosphorus supply is low and applications of phosphorus fertilizers should probably be made at the present time and will undoubtedly be needed in the future. Where truck crops are grown, the application of commercial fertilizers may be of considerable value and special brands desirable for use in the growing of certain crops may be employed with profit.

LINDLEY FINE SANDY LOAM (136)

This is a minor type in the county, covering 1.9 percent of the total area. Practically all of it occurs along the Des Moines river, the largest bodies being found west of the river in the vicinity of Camp Dodge and northwest of Polk. Areas of the type are also found in the vicinity of Des Moines and along the Raccoon river, Walnut creek and Four Mile creek.

The surface soil of this type is a grayish-brown fine sandy loam extending to a depth of about ten inches. Below this point it is a gray and brown mottled compact silty clay loam to a depth of 24 inches, then passing into a brown to yellowish-brown very compact gritty clay. Below the three foot section the material is a yellowish-brown, gritty, friable clay, mottled with gray spots which consist of calcareous material. The surface soil contains considerable very fine sand and on the flatter areas may be a very fine sandy loam. Numerous reddish-brown iron stains occur in the subsoil. A few glacial boulders occur and considerable coarse sand and gravel is found in the lower subsoil. Within this type there are included small areas of soils that are not typical. Along the steeper slopes of the Des Moines river and south of the city of Des Moines, there are exposures of drift material, mixed with silt, that are not typical. The surface material in these areas is usually a reddish-brown boulder clay, coarse sand, buff colored silt and gray sticky clay, or a mixture of all of these. The surface of these areas is almost perpendicular and they are included owing to their small extent and to the fact that they are of little value.

In topography this type is rolling to steep. It is usually found on steep slopes, altho in some places it extends over narrow rather flat divides. Where the topography is steep, the drainage is excessive and erosion has been very active, causing the formation of numerous ravines. The smoother areas are adequately drained.

Less than half of the Lindley fine sandy loam is under cultivation. It was originally a timber soil and much of it still supports a growth of oak, elm, wild cherry, hickory, hazelnut and buck brush. These areas are utilized as pasture for cattle and horses. The cultivated portion is utilized for the same crops as the Carrington fine sandy loam. Near Des Moines the type is used for the raising of truck crops.

Yields are somewhat less on this soil than on the Carrington fine sandy loam. The type is particularly in need of organic matter and should receive liberal

applications of farm manure. Where truck crops are grown, the addition of especially large amounts of this material is very desirable. If farm manure cannot be employed, leguminous crops should be utilized as green manures. Erosion may be very active in this type and some method of preventing this injurious action should be practiced if the soil is to be cultivated. It is often in need of lime and should be tested for acidity before attempting to grow leguminous crops. The phosphorus content is low and for the growth of general farm crops, phosphorus fertilizers would probably prove of value. Applications of special fertilizing materials might be of use in the growing of truck crops.

SHELBY LOAM (79)

The Shelby loam is a minor type in the county, covering 1.4 percent of the total area. It occurs in numerous small areas chiefly along the Des Moines river. There are small areas, however, thruout the northern part of the county along Four Mile creek, White Oak creek, Beaver creek and Walnut creek. Still smaller spots of this type are found along the smaller tributaries to these streams and scattered thru the Carrington upland. The larger areas usually occur in irregular strips along the streams mentioned.

The surface soil of the Shelby loam is dark brown to black in color and extends to a depth of 8 to 10 inches. The subsoil is a brown to yellowish-brown rather compact heavy loam to silty clay loam. Below 18 to 24 inches this passes into a brownish-yellow to grayish-yellow rather loose silty clay loam or sandy clay. Glacial boulders and gravel occur thruout the soil and subsoil. In the lower layers there are occasionally calcareous or lime spots and in many places the subsoil shows reddish-brown iron stains. In some of the areas on narrow ridges or knolls a layer of coarse sand and gravel is found at varying depths below the surface soil. This is the usual condition in small areas in the northern part of the county and along the west county line. On the flatter areas the soil may be almost black in color, while in the rougher topographic position it is rather light colored. Frequently the surface soil is light textured and approaches a fine sandy loam.

In topography this soil is rolling to steeply rolling. Along the river it occurs in abrupt slopes which have been eroded and contain numerous deep ravines. In the smaller areas and those at some distance from streams, the topography is ridgy or knolly and in the north central part of the county the knolls of the type rising above the Webster soils may be almost flat. In the rougher areas drainage may be excessive and in general it is entirely adequate.

Probably less than a third of this type is under cultivation, oats, corn and wheat being the principal crops grown. Corn yields 25 to 35 bushels per acre, oats 45 to 50, and fair yields of wheat are secured. Sweet corn gives 2 to 2½ tons of green ears per acre. On the more rolling areas, cultivation is almost impossible and these areas are kept in native grasses and are used for pasture. Practically all of the areas along the streams were originally forested.

On the rougher portions of the type cultivated crops should not be grown owing to the fact that the plowing up of the sod in such locations leads to very serious erosion. Such areas should undoubtedly be kept in pasture. On areas which are suitable for cultivation fairly satisfactory crop yields may be secured

in favorable seasons. Methods of preventing erosion should be practiced in all cases. The soil is low in organic matter and should receive liberal applications of farm manure. Leguminous crops may be used as green manures with profit. The type is acid and in need of lime. The phosphorus supply is low and applications of phosphorus fertilizers would probably be of value now and will certainly be needed in the near future.

LOESS SOILS

There are three loess soils in the county and these, with the shallow phase of the Tama silt loam, make a total of four loess soils. They are classed in the Tama and Clinton series and the total area covered by this group of soils amounts to 14.5 percent of the county.

TAMA SILT LOAM (120)

The Tama silt loam is the most extensive loess type in the county and it is the third largest individual soil type. Together with the shallow phase, which is minor in area, it covers 11.1 percent of the total area of the county. It occurs on the uplands in the southern part of the county, being the chief upland type in that section of the county. Practically all of it occurs in three large areas which are separated by Camp creek, Mud creek and the Des Moines river. There is also a small area north of the Raccoon river in the southwestern corner of the county.

The surface soil of the Tama silt loam is a dark grayish-brown to dark brown smooth silt loam extending to a depth of 12 or 14 inches. The subsoil is a dark yellowish-brown, heavy silt loam, grading at about 22 inches into a friable brownish-yellow light silty clay loam. Reddish-brown iron stains occur thruout the lower subsoil. The surface soil is somewhat lighter colored on the slopes, while on the divides it is deeper and darker in color. Where the surface soil is six inches or less in depth, the shallow phase has been mapped. The type is

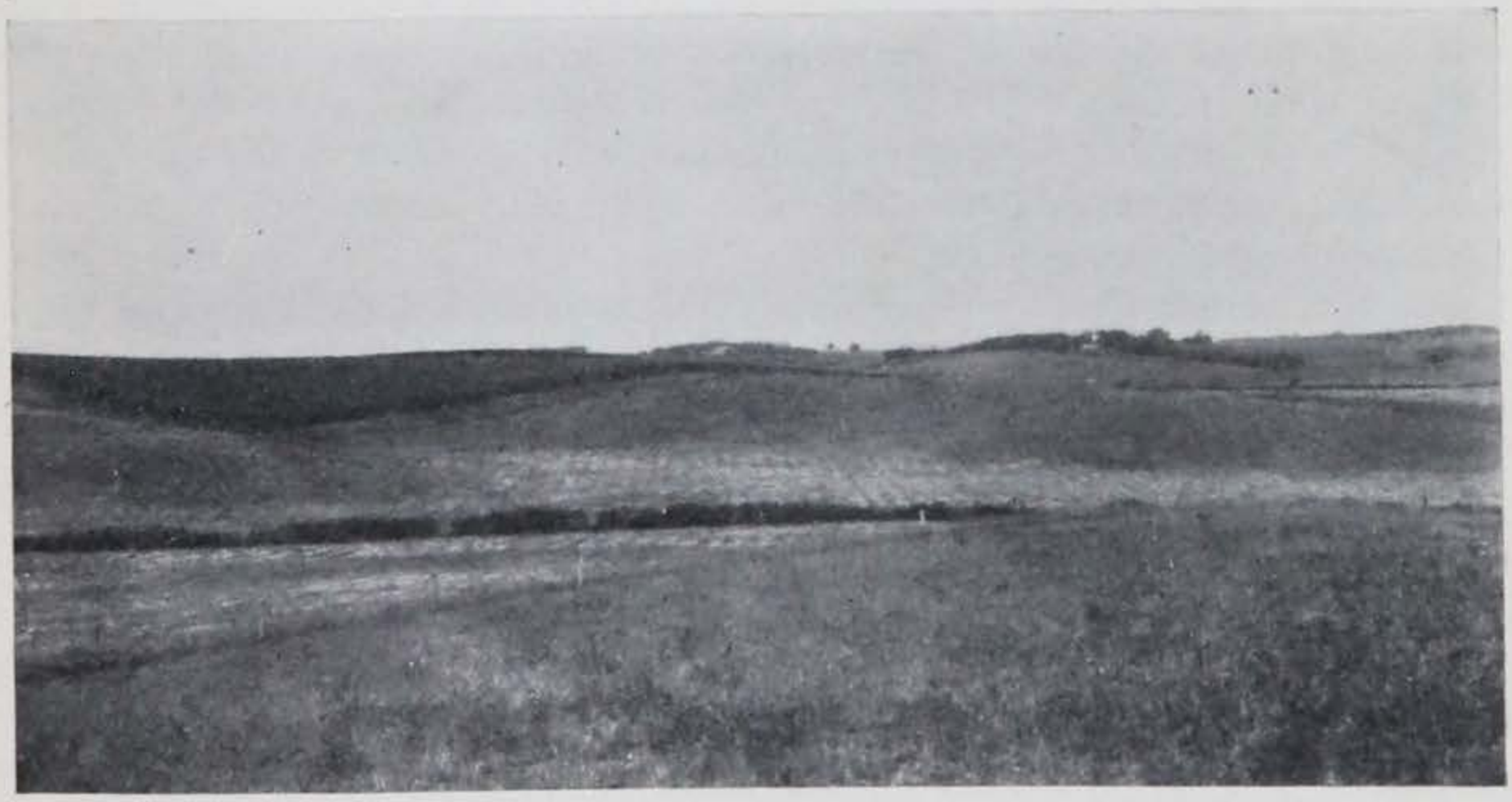

Fig. 7. Topography of Tama silt loam.

associated with the Clinton silt loam and in many cases the boundary between these two types is rather arbitrarily established, owing to the fact that there is a gradual transition from the darker colored Tama to the lighter colored Clinton.

In topography the soil is smooth to rolling. The divides are narrow and smooth and the valleys V-shaped. Along the streams the topography is more rolling. Drainage is adequate over most of the type, altho there are a few small areas along the more sluggish streams where tiling would be of value.

The Tama silt loam is nearly all under cultivation and the leading crops grown are corn, wheat and oats. Corn yields 30 to 40 bushels per acre, oats 45 to 50 bushels, winter wheat 20 to 27 bushels and spring wheat 18 to 22 bushels. Considerable hay is grown and red clover and timothy mixed yield 2 tons per acre, clover alone 1¾ to 2½ tons, timothy alone 1¼ to 1¾ tons and alfalfa 2½ to 3 tons per acre. Apples and grapes are grown to some extent. Blackberries, raspberries, strawberries, cabbage, beets, potatoes, beans and onions are grown on some of the areas south of Des Moines.

This type is rather productive and in general crop yields are fairly satisfactory. It is not particularly high in organic matter, however, and applications of farm manure are of considerable value. This material should be used in liberal amounts where truck crops are to be grown. Leguminous green manure crops might be employed in some cases to advantage. The soil is acid and in need of lime, especially for the growth of legumes. It is much better supplied with phosphorus than any of the types in the county, but applications of phosphorus fertilizers might prove of value even at the present time and certainly will be needed in the future. Where truck crops are grown the application of special fertilizer brands would probably prove profitable.

TAMA SILT LOAM—SHALLOW PHASE (143)

The shallow phase of the Tama silt loam is minor in area, covering 1.2 percent of the total area of the county. It occurs chiefly along the Des Moines river and the Raccoon river, the largest area being found south of the Raccoon river and occupied by the city of Des Moines. Other small areas occur along the heads of small drainageways or on very narrow divides in the more rolling topography. It is found in association with the Tama silt loam of the upland on the rougher areas where erosion has been active and considerable portions of the loess have been washed away.

The surface soil of the type is not more than six inches in depth and is in general dark brown in color. Frequently, however, it is a dark yellowish-brown to dark grayish-brown, due to an admixture of the yellowish-brown subsoil.

In topography this phase is rolling to strongly rolling and drainage is in places excessive. About one-fourth of the total area of the type is occupied by the city of Des Moines, and of the remainder, about 60 percent is under cultivation. It is utilized for the same crops that are grown on the typical Tama. The balance is utilized for pasture and supports a growth of prairie grasses and bluegrass, with some forest trees.

The soil on the cultivated areas is somewhat less productive than the typical Tama owing to the fact that it is shallow. It is in need of applications of organic

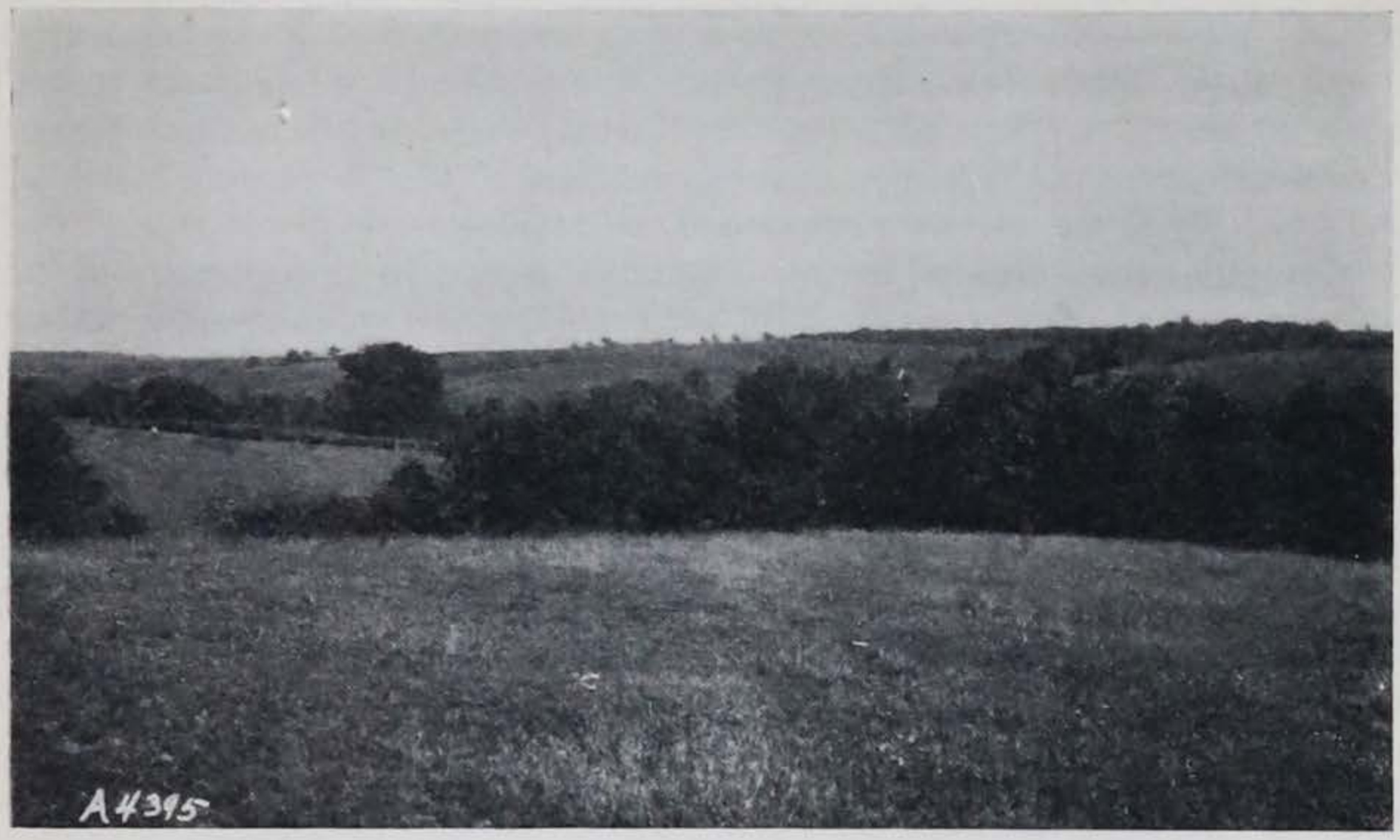

Fig 8. Clinton silt loam is rolling in topography, and drainage is good.

matter and liberal amounts of farm manure should be applied. Leguminous green manures might also be used with value. It is acid and in need of lime and applications of phosphorus fertilizers would undoubtedly prove of value. In the cultivated portion it is very important that precautions be taken to prevent erosion and some of the areas should undoubtedly be kept in permanent pasture.

CLINTON SILT LOAM (80)

The Clinton silt loam is the second largest loess type in the county, covering 3.3 percent of the total area. It occurs in the southern tier of townships across the county along the Des Moines and Raccoon rivers and is associated with the Tama silt loam of the upland. The largest area occurs in Four Mile township southeast of Des Moines. Another considerable area is found along Camp creek in the southeastern corner of the county. Smaller areas occur along the Raccoon river and the various tributaries to this stream.

The surface soil of the Clinton silt loam is a brown to light brown or grayish-brown smooth silt loam extending to a depth of about seven inches. The subsoil is a mottled brown or brownish-yellow and gray heavy silt loam passing at about 18 inches into a brownish-yellow or yellowish-brown very compact clay. Occasionally the brown and gray mottling may continue thru the lower subsoil. In places on the slopes some smooth very fine sand may occur in the surface soil. In uncleared areas the organic matter content in the surface soil may be somewhat higher than the typical and the color a little darker.

In topography this type is rolling and drainage is good. Excessive washing occurs on some of the steeper slopes. About one-half of the type is used for pasture and a large portion of this is occupied by forest trees. The less rolling areas are nearly all under cultivation with wheat, corn and oats the principal crops

grown. Winter wheat yields 18 to 25 bushels per acre, oats 35 to 40 bushels and corn 20 to 30 bushels. Fruit growing and trucking are important industries near Hastie and there are several small commercial orchards in this locality. Apples and grapes do well when properly handled. Potatoes produce satisfactory yields when the organic matter supply is sufficient.

This soil is somewhat less productive than the Tama soils owing largely to its lower content of organic matter. Its chief need is for applications of farm manure and if this is not available, the use of leguminous green manures would prove profitable. It is acid in reaction and should be limed. It is low in phosphorus and applications of phosphorus fertilizers would be of value for the growth of cultivated crops. On some of the rougher portions the soil should undoubtedly be left in pasture and on many of the areas under cultivation protection from erosion is very necessary if satisfactory crop yields are to be secured and the soil kept from serious washing.

TAMA LOAMY FINE SAND (145)

This is a very minor type in the county, covering only 0.1 percent of the total area. It is developed in small areas along the Raccoon river and some of the minor drainage channels in the southwestern part of the county and almost entirely within Bloomfield township.

The surface soil of the type is a dark grayish-brown loamy fine sand underlaid at about 15 inches by a lighter colored loamy fine sand or fine sand. In the areas joining the other uplands the surface soil may be somewhat heavier than the typical. It occurs on the slopes to drainageways and drainage is usually excessive.

Most of the type is used for pasture. Corn, wheat and oats are grown to some extent but the yields of these crops are rather low, particularly in dry seasons. Watermelons, cantaloupes and cucumbers grow well on the soil when it has received liberal applications of manure. This type is particularly in need of organic matter if it is to be cultivated and farm manure should be used as far as possible and if this material is not available, leguminous crops should be used as green manures. With a proper supply of organic matter in the soil, crops will not be so subject to injury from drouth. The soil is acid and in need of lime. The phosphorus content is low and phosphorus fertilizers would be necessary for the best growth of crops. Special brands of fertilizers may probably be used to advantage where truck crops are to be grown.

TERRACE SOILS

There are eleven terrace types in the county, classified in the Waukesha, Bremer, O'Neill, Buckner and Chariton series. The terrace types together cover 11.4 percent of the total area of the county.

WAUKESHA LOAM (60)

The Waukesha loam is the largest individual terrace type in the county, covering 3.7 percent of the total area. It occurs in all parts of the county on narrow terraces along the various streams. The largest areas are found in the vicinity of Camp Dodge, along Beaver creek and near Des Moines along the Des Moines river, a large part of the city being located on this type. Other

considerable areas occur in the northeastern part of the county along Indian creek and Skunk river. Small areas are found along many of the other streams of the county.

The surface soil of the Waukesha loam is a dark brown friable loam extending to a depth of about 15 inches. This is underlaid by a brown heavy loam which passes into a brown to yellowish-brown or brownish-yellow friable silty clay loam. On the more level areas the surface soil of the type is rather dark in color, while on the slopes it becomes lighter than the typical. Ocassionally glacial gravel or pebbles are found in the soil section. In the southern part of the county the loam is derived mainly from the loess of the uplands. The subsoil is in general rather compact in structure, but in the areas north of the Skunk river and west to Beaver creek, the subsoil is open and very friable. In the latter location there are small areas where the soil somewhat resembles the Shelby loam. These areas are very minor in extent. In the area along the Story county line in the northeastern corner of the county, the surface soil is heavier than typical, approaching a silty clay loam. The subsoil is a dark yellowish-brown silty clay loam which becomes lighter in color and more compact at the lower depths.

In topography this soil varies from flat to gently undulating or sloping. Along the smaller creeks it lies from 5 to 10 feet above the first bottoms. Along the larger creeks and rivers it may lie as high as 40 feet above the overflow land. The type in general is very satisfactorily drained and the subsoil conditions are such that it is not drouthy.

About 80 percent of the Waukesha loam is under cultivation, a small proportion being occupied by towns and farmsteads or used for pasture. The most important grain crops are corn, oats and wheat. Corn yields 35 to 40 bushels per acre, oats 35 to 45 bushels, winter wheat 20 to 27 bushels and spring wheat 18 to 21 bushels. Hay is grown to some extent and clover and timothy mixed produce 1½ tons per acre, clover alone 1½ to 1¾ tons and timothy alone 1¼ to 1½ tons. Alfalfa has been grown to some extent on the type and gives very satisfactory yields. Some sweet corn is grown in the northeastern part of the county and sold to the canning factories.

The Waukesha loam is rather a productive type and crop yields are fairly satisfactory. They may be increased, however, by proper soil treatments. The soil will respond to applications of manure and all the manure produced on the farm should be carefully stored and returned to the land. If manure is not produced in sufficient amounts, leguminous crops should be used as green manures. The soil is acid and in need of lime and this material should be used if the best growth of legumes is to be secured. Applications of phosphorus fertilizers may be needed in the future and tests of these materials are urged at the present time.

BREMER SILTY CLAY LOAM (43)

The Bremer silty clay loam is a minor terrace type, covering 1.8 percent of the total area of the county. It occurs along the bottomlands of the Skunk river, the Des Moines river and the Raccoon river in rather extensive areas. Smaller narrow strips are found along the bottoms of some of the minor streams of the county. The largest area of the type is along the Des Moines river south

and east of Des Moines. Another rather extensive area is found along the Raccoon river, the city of Valley Junction being very largely located on this type. A third area which is rather extensive is found along the Skunk river in the northeastern part of the county.

The surface soil of the Bremer silty clay loam is a dark brown to nearly black silty clay loam. This grades at about 18 inches into a dark brown to dark brownish-gray rather tough clay. Numerous rusty brown iron stains are found in the subsoil. Small spots of the loam occur within these silty clay loam areas, but they cannot be shown on the map because of their small extent. The boundary lines between this type and the silt loam and loam of the same series are rather arbitrarily drawn, as there is usually a gradation from one type to the other. In areas adjoining the Bremer clay and where the soil is poorly drained, there is a higher clay content and the subsoil may be a nearly black dense clay. This is true in the areas west of the Skunk river. In the areas near Loring the lower subsoil is brownish-gray to drab in color. Occasionally in the same areas in this locality in the higher-lying parts of the type, the lower subsoil may be a brown to brownish-yellow or grayish-yellow clay. Along the smaller streams there may be some gravel in the lower subsoil and in a few small areas along Beaver creek, the lower subsoil has a yellowish to grayish cast and lime occurs thruout the soil section. In these areas the soil really should be in the Fargo series but is not separated owing to its small extent. In the area along Indian creek in the northeastern part of the county, the soil is underlaid at about thirty inches by a layer of coarse sand and gravel.

In topography the Bremer silty clay loam is nearly level, in some cases sloping very gently toward the streams. Practically all of it is above ordinary floods but occasionally there are areas which are said to have been overflowed once or twice during the past forty years. Along the Des Moines river the terrace level is 10 to 15 feet above the present stream bed. Along the Skunk river and bordering the creeks it is 2 to 10 feet above overflow land. Drainage of the type is fair but on the more level areas water may stand for considerable time following heavy rains. The installation of tile has proven of advantage in many cases in handling this soil.

The Bremer silty clay loam is practically all under cultivation except for the land occupied by farmsteads and towns and a very few small pastures. The most important crops are corn, oats, wheat and hay. The yields of these crops are very much the same as on the Carrington loam, the hay crops frequently giving much higher yields than the grain crops. This soil is particularly in need of adequate drainage in order to make it more productive. It is very important that tile be installed in practically all cases in order to prevent injury to crops from excessive moisture. The soil is well supplied with organic matter but it would respond to a small application of manure when it is newly drained. It is acid and in need of lime. Phosphorus fertilizers will certainly be needed in the future and they may be of value in some cases at the present time.

O'NEILL FINE SANDY LOAM (110)

The O'Neill fine sandy loam is a minor terrace type, covering 1.3 percent of the total area of the county. It occurs on the higher terraces along the Des Moines river and its larger tributaries from Des Moines north and along Indian

creek. The largest areas of the type are found north of Des Moines partly within the city limits and in the vicinity of Johnston. The other areas of the type are practically all small and relatively unimportant.

The surface soil of this type is a dark brown to dark grayish-brown fine sandy loam 12 to 15 inches in depth. The subsoil is a dark brown to brown fine sandy loam, grading at about 27 inches to a lighter colored sand, and below this there is a layer of gravel and sand. In a few small areas along the upper course of the Des Moines river, along Beaver creek west of Camp Dodge and on Big creek, Four Mile creek and Indian creek, the lower part of the three foot section is a mixture of gravel and coarse sand.

In topography the soil is usually gently undulating to sloping or level. The terraces of the type are practically all above overflow. The soil is excessively drained and apt to be drouthy.

Probably 70 percent of the type is under cultivation, the chief crops being corn, wheat and oats. Some of the smaller areas are used for pasture. On the areas near Avon Station close to Johnston and north of Des Moines, truck growing is an important industry and watermelons, cantaloupes, sweet potatoes, cucumbers, tomatoes and cabbage are grown successfully. Early sweet corn does well also.

This soil is chiefly in need of organic matter in order to increase its ability to hold moisture during dry weather. Large applications of farm manure are very desirable. On the areas where trucking is practiced, particularly large applications of farm manure should be made. Leguminous green manure crops may often be used with profit on this type. It is acid and in need of lime. Applications of phosphorus fertilizers would probably be of value now for general farm crops and will certainly be needed in the near future. Where truck crops are grown, the application of brands of commercial fertilizers prepared for special crops would probably prove profitable.

BREMER SILT LOAM (88)

The Bremer silt loam is a minor terrace type, covering 1.2 percent of the total area of the county. It occurs along the Des Moines river, the Raccoon river and along Camp and Mud creeks. The largest areas are found directly north of Des Moines and south of Hastie along the Des Moines river, south of Des Moines and south of and west of Valley Junction along the Raccoon river. The areas along Mud creek and Camp creek are very small and relatively unimportant.

The surface soil of the Bremer silt loam is a dark brown to nearly black silt loam extending to a depth of about 14 inches. The subsoil is a dark brown silty clay loam grading gradually into a dark brownish-gray or grayish-brown silty clay loam. Along Camp and Mud creeks the soil has a brownish-gray or mottled dark brown and gray silty layer six to eight inches thick in the upper subsoil. In many of the smaller areas the color of the soil changes very little thruout the three foot section.

In topography this soil is level or slopes gently toward the streams. It is found on terraces 5 to 15 feet above the present stream channels. The type is fairly well drained and tiling is not generally needed.

Practically all of the Bremer silt loam is under cultivation, corn, wheat, oats and hay being the principal crops grown. Some sweet corn is produced in the

vicinity of Des Moines. Yields of these crops are much the same as on the Bremer silty clay loam.

This is a rather productive soil and crop yields are generally fairly satisfactory. Small applications of farm manure would be of value but it is not advisable to apply this material immediately preceding the oats crop of the rotation owing to the danger of causing it to lodge. The type is acid and in need of lime. It will probably respond to applications of phosphorus fertilizers at the present time and in any case these materials will be needed in the near future. In some areas tiling may be of value if drainage conditions are not entirely satisfactory.

BREMER LOAM (12)

The Bremer loam is a minor type in the county, covering 0.9 percent of the total area. It occurs in small areas along the Des Moines river, Skunk river and Beaver and Walnut creeks. The largest areas are along the Des Moines river, north of Lovington and south of Des Moines.

The surface soil of this type is a dark brown friable loam extending to a depth of about 15 inches. This is underlaid by a very dark brown silty clay loam which below 24 inches passes into a dark brownish-gray or grayish-brown silty clay loam. In the more level areas the lower subsoil is quite compact. In the areas near the mouth of the North river there is considerably gritty material in the lower subsoil. A few areas lying along Beaver creek are highly calcareous and are really Fargo soils but they are too small to be shown separately on the map. In topography this soil is level to gently sloping. It occurs on terraces two to five feet above the overflowed bottomland. Most of the soil is above overflow except during periods of very high water. Most of the Bremer loam is under cultivation and the crops grown are the same as on the Bremer silty clay loam. The yields secured are very much the same as on the silty clay loam. This type is well drained and not in need of tiling. Small applications of farm manure would be of value. It is acid and in need of lime and applications of phosphorus fertilizers would probably prove of value in most instances.

BUCKNER FINE SANDY LOAM (45)

This is a minor terrace type in the county covering 0.7 percent of the total area. It occurs in small areas along the Skunk river, Beaver creek and the Des Moines river. The largest area is along Beaver creek north and west of Camp Dodge and there is also a rather considerable area in the northeastern part of the county along the Skunk river.

The surface soil of this type is a dark brown fine sandy loam extending to a depth of 12 to 18 inches. The subsoil is a dark brown to yellowish-brown fine sandy loam, which is quite loose and incoherent in the lower part of the three-foot section.

The topography of the soil is level to gently undulating. The soil is well drained but the drainage is rarely excessive. It occurs on high terraces, some of which are five to ten feet above the first bottoms, while others lie 25 feet above overflow land.

Probably 85 percent of the type is under cultivation, corn, oats and wheat being the principal crops grown. Watermelons, cantaloupes, sweet potatoes, cucumbers and tomatoes are grown to some extent on the type and give very

satisfactory yields. A small portion of the type is used for pasture, being kept in native grasses or bluegrass.

This soil is particularly in need of organic matter and should receive liberal applications of farm manure in order to make it more productive. Leguminous green manure crops might be used to advantage. It is acid and in need of lime and phosphorus fertilizers will certainly be necessary in the near future.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is a minor type in the county, covering 0.7 percent of the total area. It occurs mainly in the southern part of the county along the Des Moines river, the Raccoon river and their tributaries. A few areas are found in the northern part of the county, one west of Johnston, one west and one south of Polk and a fourth three miles northwest of Santiago.

The surface soil of this type is a dark brown to nearly black smooth silt loam about 14 inches in depth. The subsoil is a yellowish-brown to brownish-yellow rather compact heavy silt loam to light silty clay loam. In a few of the smaller areas adjoining the Clinton silt loam in the southeastern part of the county, there is a shallow layer of dark gray silt loam on the surface. In the more level portions of the type southwest of Runnells the soil is heavier than typical and almost a silty clay loam.

In topography the type is flat to gently sloping. Drainage is good. The type occurs 10 to 40 feet above the stream channels and hence it is not subject to overflow. Practically all of the Waukesha silt loam is under cultivation, the principal crops grown being corn, oats, and wheat. Yields are very much the same as on the Waukesha loam and the treatment needed for the soil is very similar. Applications of farm manure would be very desirable. The soil is acid and in need of lime and phosphorus fertilizers would probably prove of value.

O'NEILL LOAM (108)

The O'Neill loam is a minor type in the county, covering 0.6 percent of the total area. It occurs in small disconnected areas along the Des Moines river, above the mouth of the North river, along the larger creeks in the western part of the county and along Indian creek in the northeastern part of the county. The areas are all small and none include over 200 acres.

The surface soil is a dark brown to dark grayish-brown loam 10 inches in depth. The subsoil to a depth of 24 inches is a brown loam to light silty clay loam which gradually becomes sandier at lower depths and is underlaid by a layer of gravel, coarse sand and small boulders. In the flatter areas the surface soil may be quite silty while in the more undulating areas it may become lighter textured. Frequently considerable coarse sand and gravel are found in the surface and thruout the soil section. Occasionally the supply of organic matter is so low that the surface soil is brown in color.

The topography of this soil is nearly level to gently undulating. Drainage is good to excessive and the soil is apt to be drouthy. It lies on high terraces 10 to 40 feet above the bottomlands.

Practically all of the larger areas of the type are under cultivation, the smaller ones being used for pasture. The crops grown are the same as on the Waukesha loam and the yields secured are very similar, except in dry years, when the yields are considerably reduced.

This type is particularly in need of organic matter to make it more productive and permit of the better retention of moisture. Liberal applications of farm manure are very desirable and leguminous green manure crops may be used in some cases to advantage. The soil is acid and in need of lime. Applications of phosphorus fertilizers may prove profitable at the present time. They will certainly be needed in the future.

BREMER CLAY (44)

The Bremer clay is a minor type in the county, covering 0.3 percent of the total area. It occurs in many small areas along the various streams of the county and one large area south of Saylorville. Areas are found along Walnut creek, the Des Moines river and the Skunk river.

The surface soil of this type is a nearly black crumbly clay extending to a depth of about 18 inches. The subsoil is a very dark brown compact clay grading into a dark brownish-gray clay. In a few of the smaller areas the subsoil may have a pale yellow cast. In general, the entire soil section is dark in color and there is no distinct line of division between the soil and subsoil.

In topography the soil is level and drainage is poor. The installation of tile and the use of ditches will be necessary in order to make this soil more productive. It lies above ordinary floods but may overflow infrequently. Most of the small areas of this type are under cultivation, the same crops being grown as on the Bremer silty clay loam. The soil is apt to clod if plowed when too wet and will bake and crack upon drying. It is a late soil unless very well drained. Part of the larger areas is kept in native grasses and used for hay and pasture, yields of hay amounting to 1½ tons per acre annually.

The soil is particularly in need of drainage in order to make it satisfactorily productive. When this is accomplished it may be desirable to make a small application of farm manure in order to encourage the production of available plant food. It is generally acid and in need of lime and applications of phosphorus will be needed in the future.

O'NEILL FINE SAND (146)

The O'Neill fine sand is a very minor type in the county, covering 0.1 percent of the total area. It occurs in very small areas along the Skunk river in the form of low mounds rising in the areas of first bottom. Four other small areas are mapped with this soil because of their small extent. One is north of Polk, one north of Andrews, one south of Berwick and the other south of Peoria City. These areas are gravel pit residues and consist of a mixture of gravel, coarse sand and some clay. They are of no agricultural value.

The O'Neill fine sand has a grayish-brown to brown surface color and changes gradually into a yellowish-brown at lower depths. When it contains considerable organic matter, the surface may be dark grayish-brown in color.

In topography the soil is flat, the areas rising from 5 to 15 feet above the surrounding bottomland. Drainage is adequate to excessive. The soil is inclined to blow if not kept in cover crops.

Most of the O'Neill fine sand is used for pasture, supporting only a sparse growth of native prairie grasses. The remainder is cultivated with the adjacent soils or is occupied by farmsteads. Corn yields are generally unsatisfactory and small grains do not produce well. Some vegetables are grown for home use.

This type is particularly in need of organic matter and should receive liberal applications of farm manure and, if this material is not available, leguminous green manure crops should be employed. The soil is acid and in need of lime. Phosphorus is low and phosphorus fertilizers would prove of value. In areas where truck crops are grown commercial fertilizers might be used with profit. With these treatments the soil may be made to produce as satisfactory general crops as the surrounding areas.

CHARITON SILT LOAM (105)

The Chariton silt loam is a very minor type in the county, covering only 0.1 percent of the total area. It occurs in several small areas in the county, three of them south of Camp Dodge and three southeast of Avon Station.

The surface soil is a dark gray to dark grayish-brown smooth silt loam extending to a depth of about 9 inches. From this point up to 20 inches the subsoil is a gray to light gray ashy silt loam. The lower subsoil is a drab colored impervious clay slightly mottled with brown. The lower subsoil is mottled with numerous reddish-brown iron stains. In one of the largest areas the subsoil shows some reddish-yellow mottlings in the lower depths. In the smaller areas the surface soil varies from a loam to a heavy fine sandy loam.

This soil occurs above overflow but water stands on it for long periods after heavy rains, owing to the impervious character of the subsoil. Drainage is very poor and tiling is necessary if the soil is to be utilized for cultivated crops.

Part of the type is in grass and used for pasture, the chief grasses being bluegrass and red top. On the cultivated areas corn, oats and wheat are grown. Fair yields of these crops are secured in normal seasons if the drainage is adequate. This is the first treatment needed for the soil. It would then respond to applications of farm manure. Lime should be used if needed and applications of phosphorus fertilizers would probably prove of value.

SWAMP AND BOTTOMLAND SOILS

There are 13 swamp and bottomland soils in the county and together they cover 14.0 percent of the total area. They are classified in the Wabash, Sarpy and Lamoure series.

WABASH CLAY (72)

The Wabash clay is the most extensive bottomland type, covering 4.1 percent of the total area of the county. It is developed primarily along the Skunk river, about 90 percent of it occurring in the bottoms along this stream. Other areas are mapped along the Des Moines river near Youngstown, south of Lovington and in the vicinity of Adelphi and Levey. There are also small areas along Indian creek and the Raccoon river. Along the Skunk river practically the entire bottoms are occupied by this type, while in the other areas the soil occurs in narrow strips and is associated with other bottomland types.

The surface soil of the Wabash clay is a very dark brown to nearly black clay. There is a very gradual change to the subsoil which is somewhat lighter in color and more plastic. It is usually a dark brownish-gray but may be drab colored in the smaller areas. It contains numerous iron stains. Small amounts of sand occasionally occur thruout the soil and near the stream

channels a layer of sand two to three inches deep may cover the surface. In some of the narrower areas along the Des Moines river the soil may be lighter in color than the typical and occasionally there is a layer of sand in the lower part of the three foot section.

In topography the Wabash clay is flat. It is subject to overflow nearly every year except for the area south of Youngstown which is seldom flooded. The drainage of the type in general is poor. Water often stands on the surface after heavy rains and in the lower parts of the type the soil is somewhat marshy.

Less than 40 percent of the Wabash clay has been brought under cultivation, chiefly because of the unsatisfactory drainage of the type and because of the danger of overflow. In the cultivated areas corn is grown most extensively and wheat and oats are of secondary importance. Under favorable seasonal conditions corn produces from 40 to 70 bushels per acre and wheat 20 to 30 bushels per acre. Sweet corn is grown to some extent in the area along the Skunk river and the product sold to the canning factories. The yield of this crop amounts to 3 to 5 tons of ears per acre. On the stream banks there is some tree growth, consisting mainly of oak and elm. The greater part of the uncultivated land supports a luxuriant growth of slough grasses and is used for the production of hay and for pasture land. Slough grass produces from one to two tons of hay per acre and about 30 percent of the slough grass is cut for hay. The hay produced from the coarser leaved varieties is sold for packing purposes while that from the finer varieties is used for feed.

The chief need of the Wabash clay, if it is to be cultivated, is for adequate drainage. It should also be protected from overflow if crops are to be grown satisfactorily each year. It must be cultivated very carefully as it will clod and pack if plowed when too wet and it must be handled when the moisture content is just right if the physical condition is to be satisfactory thruout the season. It is very sticky when wet and cracks upon drying. The soil is apt to be in need of lime, especially after it has been drained and cultivated. A small application of farm manure would be of some value when the type is newly drained, but it is ordinarily very well supplied with organic matter. The phosphorus content will become deficient in the near future.

WABASH LOAM (49)

The Wabash loam is the second largest bottomland type in the county, covering 2.3 percent of the total area. It occurs chiefly along the various creeks of the county. Thus it is the main type in the bottoms along Four Mile creek, Walnut creek, Beaver creek and Big creek. Other areas are found along White Hall creek, Little creek, the upper parts of Mud creek and Camp creek. There are areas of the type also along the Des Moines river. It is found in long narrow areas ranging in width from a few hundred feet to a quarter of a mile and may occupy all or nearly all of the creek bottoms.

The surface soil of the Wabash loam is a dark brown to nearly black mellow loam 18 inches in depth. The subsoil is a dark brown to dark brownish-gray silty clay loam. In many places there is very little variation in the soil thruout the three foot section, but in general the subsoil is more compact than the surface. The surface soil is somewhat variable in texture, being heavier in the

lower lying parts of the type back from the stream channels and sandier near the banks where it is most frequently overflowed. In some of the very narrow stream bottoms, the surface soil may vary from a fine sandy loam to a heavy loam.

In topography the Wabash loam is flat, but drainage is fair, owing to the old channels and sloughs which permit of the removal of excess moisture. Most of the type is subject to overflow, but the areas along the Des Moines river occupy somewhat higher positions than those along the creeks and they are subject to less frequent overflow.

Less than 20 percent of the Wabash loam is under cultivation, most of the type being used for pasture or for the production of hay. The small areas along the Des Moines river and some areas along Four Mile, Walnut and Big creeks are cultivated, corn, oats and wheat being the principal crops grown. Corn yields 40 to 45 bushels per acre, wheat 20 to 25 and oats 35 to 45 when the type is well drained, and in favorable seasons. Wild grasses grown on the uncultivated portion yield from 1 to 1½ tons of hay per acre. There are belts of timber on the type along the stream channels and this timber consists mainly of oak, elm, locust, hickory, black walnut and cottonwood.

Like the Wabash clay this soil is primarily in need of protection from overflow if satisfactory crops are to be grown each year. It is not so definitely in need of drainage as is the Wabash clay but in some instances drainage is necessary on the type. A small application of farm manure would be of value when the soil is newly drained and brought under cultivation. Phosphorus will eventually be needed but the type is fairly well supplied at present. It will undoubtedly become acid and in need of lime after it is brought under cultivation and well drained. The particular sample tested and reported in the analyses earlier in this report showed a basic reaction but this would not be true for the type as a whole.

SARPY LOAM (91)

The Sarpy loam is the third largest bottomland type, covering an area of 1.7 percent of the county. It occurs along the Des Moines and Raccoon rivers in relatively narrow strips varying in width from a few rods to ⅜ of a mile. The largest area is along the Raccoon river extending from the city of Des Moines beyond Valley Junction. There are many small areas of the type along the Des Moines river, particularly in the southern part of the county.

The surface soil of the Sarpy loam is a grayish-brown to brownish-gray friable loam extending to a depth of about 15 inches. The subsoil is a grayish-brown heavy loam to light silty clay loam which grades at 30 inches into a grayish-brown or a light grayish-brown very fine sandy loam to loamy sand or sand. The surface soil frequently contains much very fine sand and in the higher lying areas fine sand may occur thruout the soil section with the coarser textured subsoil nearer the surface. In the lower lying areas the surface soil of the type may be dark grayish-brown in color and quite silty in texture. In these areas the lower subsoil is usually a very fine sandy loam or light loam. There are some areas where the texture changes very little thruout the three foot section.

In topography the Sarpy loam is flat to very gently undulating. The drainage of the type, however, is good to excessive. On the higher areas where the

Fig. 9. A view over the river, showing Sarpy soils in the bottoms.

coarse subsoil layer is nearer the surface, crops may suffer from drouth. In general, however, the type is not excessively drained but adequately so. It is all subject to overflow.

About 75 percent of the type is under cultivation, the remainder being occupied by towns or in pasture. In the latter areas there is some timber, consisting mainly of oak, ash, elm, walnut, willow and haw and there is a good growth of native grasses. On the cultivated areas corn is the most important crop, followed by wheat and oats. When protected from overflow corn yields 40 to 50 bushels per acre, oats 35 to 45 and wheat 20 to 25 bushels per acre. Clover and timothy yield from 1¼ to 1¾ tons of hay. Truck crops are grown to some extent on the type, chiefly near Levey. These consist chiefly of sweet corn, tomatoes, cabbage and beets, and the product is sold in the Des Moines markets.

This type is chiefly in need of protection from overflow if cultivated crops are to be grown successfully. It is basic in reaction and contains sufficient lime so that this material will not be needed for many years. It would be benefited by applications of farm manure and in the case of truck crops liberal applications of this material should be made. Phosphorus fertilizers will be needed in the near future and might be of value at the present time.

LAMOURE SILTY CLAY LOAM (111)

The Lamoure silty clay loam is a minor type in the county, covering 1.4 percent of the total area. It occurs along the creeks and smaller drainageways in the northern part of the county, being found in narrow strips along the smaller streams, in larger areas lying back from the stream channels and the larger creek bottoms and also in old lake beds or sloughs recently drained.

The surface soil of the Lamoure silty clay loam is a very dark brown to nearly black silty clay loam, extending to a depth of about 20 inches. The subsoil is a dark drab clay becoming somewhat lighter in color at the lower depths. In the smaller areas the lower subsoil appears somewhat yellowish and contains

some coarse sand. Brown to reddish-brown iron stains frequently occur in the lower subsoil. Both soil and subsoil are highly calcareous. Where the type adjoins higher lying sandy soils there may be a surface covering which is distinctly loamy while near the center of the larger areas, the surface soil may be very heavy in texture.

This soil is level in topography and drainage is naturally poor. Water may stand on the surface for long periods after heavy rains. The type is generally subject to annual overflow.

About half of the area of this type is in native slough grasses and is utilized for pasture. The remainder of the type which has been drained with open ditches and tile, is used for the production of corn and on well drained land yields of 40 to 50 bushels per acre of this crop are secured. Small acreages are used for small grains but these are inclined to grow too rank in wet seasons.

This type is particularly in need of drainage and protection from overflow if it is to be cultivated. It must also be handled with care and not plowed or cultivated when too wet, as it is inclined to form clods. It also bakes and cracks in dry seasons. It is high in organic matter content and not particularly in need of applications of manure. However, small applications of fresh manure might be of value when the land is newly drained. Eventually it will need phosphorus. It is high in lime and should not be in need of this material for many years to come.

SARPY SILTY CLAY LOAM (144)

This is a minor type in the county, covering 1.3 percent of the total area. It occurs in the first bottoms along the Des Moines and Raccoon rivers. It is usually found along the older channels and sloughs, some distance back from the streams. The most extensive area of the type is found along the Des Moines river within the city limits.

The surface soil is a grayish-brown to dark grayish-brown silty clay loam extending to a depth of about 15 inches. This is underlaid by a dark brownish-gray silty clay loam grading at about 30 inches into a brownish-gray very fine sandy loam. In the lower lying areas there is more organic matter in the soil and it is a dark grayish-brown in color. Small areas of the silty clay or clay are included with this type, as they are too small to separate out. The texture of the lower subsoil is extremely variable and may range even in a single area from a very fine sand to a light silty clay loam. The entire three foot section of the soil is calcareous.

In topography the Sarpy silty clay loam is flat to undulating. Drainage on the lower areas is poor. Most of the type is subject to frequent overflow altho in the higher lying areas it is flooded only frequently.

Probably 60 percent of the type is under cultivation, the crops grown being corn, oats and wheat. Some sorghum is grown for sirup and for forage. Sweet corn is an important truck crop. On the lower lying areas the land is used for pasture and most of it is in grass and timber.

This soil is chiefly in need of protection from overflow if satisfactory yields of cultivated crops are to be secured. In some areas it may be in need of drainage but in general the drainage is fairly satisfactory. It is not in need of lime

but would respond to applications of farm manure and phosphorus fertilizers will be needed in the future.

SARPY VERY FINE SANDY LOAM (28)

This is a minor type in the county, covering 0.9 percent of the total area. It occurs along the Des Moines and Raccoon rivers, being developed in strips varying in width from a few rods to half a mile along the channels of the streams.

The surface soil is a grayish-brown to brownish-gray very fine sandy loam extending to a depth of about 27 inches. Below this point the subsoil is a brownish-gray to gray very fine sand. On some of the minor elevations the surface 8 to 10 inches may be a very fine sand. Both soil and subsoil are highly calcareous.

In topography the type is billowy or gently undulating and the land is well drained. It lies 5 to 15 feet above the bed of the streams but is subject to more or less frequent overflow.

Much of the Sarpy very fine sandy loam supports a forest growth consisting of oak, elm, ash, walnut, cottonwood and willow. These areas are in grass and are used for pasture. Where the soil is cultivated the chief crop grown is corn; oats and wheat being grown to some extent also. Some sorghum is produced on this land and good yields of sweet potatoes, melons, cantaloupes, tomatoes, cabbage and beans are secured.

The soil is chiefly in need of protection from overflow if it is to be used for cultivated crops. Applications of farm manure would be of large value especially where truck crops are to be grown. It will be in need of phosphorus in the near future and phosphorus fertilizers might be of value now. For truck crops certain special brands of commercial fertilizers might be employed in certain cases.

WABASH SILTY CLAY LOAM (48)

This is a minor type in the county, covering 0.8 percent of the total area. It occurs chiefly along the Skunk river and Indian creek and along the Des Moines river south of Des Moines. It is found in numerous small areas along these streams, the larger areas occurring along the bottomlands of the Skunk river.

The surface soil of the Wabash silty clay loam is a very dark brown to nearly black silty clay loam extending to a depth of about 18 inches. The subsoil is a dark brown or dark brownish-gray rather compact clay loam or clay. In many places the lower subsoil is brownish-gray or drab. It contains numerous reddish-brown iron stains. Along the Skunk river the surface soil frequently contains considerable sand.

In topography this soil is flat and drainage is very poor. Water stands on the surface for some time after heavy rains. In general the type is subject to more or less frequent overflow, some of the areas along the Des Moines river being somewhat higher than the general level of the bottoms and being flooded only infrequently.

Most of the type is under cultivation, the same crops being grown as on the Wabash loam and the yields secured are very much the same. The uncultivated portion is in native grasses and is used for pasture and hay land.

This type is particularly in need of adequate drainage and protection from overflow if cultivated crops are to be grown successfully. It is also important that it be properly handled and it should not be plowed when too wet as clods form readily and are difficult to break up by later cultivation. The soil is well supplied with organic matter but small applications of farm manure might be of value when it is newly drained. It is not generally basic in reaction and will be in need of lime when brought under cultivation. Phosphorus fertilizers will be needed in the future.

WABASH SILT LOAM (26)

This is a minor type in the county, covering 0.5 percent of the total area. It occurs entirely in the southern part of the county in the loessial area, being developed in long narrow strips from a few rods to one-seventh of a mile in width and covering nearly the whole of the first bottoms along the lower courses of Camp creek, Mud creek, Spring creek and Yeader creek. Small areas are also found along the Des Moines river and along the Raccoon river.

The surface soil of this type is a dark brown to nearly black loam extending to a depth of about 18 inches. The subsoil is a very dark brown silty clay loam becoming a brownish-gray in the lower part of the three-foot section. In areas adjacent to the Clinton silt loam the surface frequently has a shallow covering of lighter colored loessial material. In the small areas lying about two miles east of Avon Station the surface soil is shallower than typical and the subsoil is dark yellowish-brown.

The topography of the type in general is flat, altho the surface is broken in many places by old stream channels. The drainage of the soil in general is poor. Practically all of it is subject to annual overflow except the higher lying areas in the Des Moines river bottoms.

With the exception of the same small areas, the type is practically all in native grasses and forest and is used for pasture. The areas in the Des Moines river bottoms are generally cultivated and corn, oats and wheat are the principal crops grown. Yields are very much the same as on the Wabash loam.

The soil is fairly productive when protected from overflow and adequately drained. It will respond to applications of farm manure and lime, as it is generally acid. Phosphorus fertilizers will be needed in the future.

SARPY SILT LOAM (89)

The Sarpy silt loam is of minor importance in the county, covering only 0.3 percent of the total area. It occurs along the Des Moines river and the Raccoon river mainly south of Johnston, larger areas occurring east of Valley Junction and south of Commerce along the Raccoon river.

The surface soil of the Sarpy silt loam is a grayish-brown silt loam extending to a depth of about 15 inches. The subsoil to a depth of 30 inches is a brownish-gray to grayish-brown heavy very fine sandy loam. Below 30 inches it becomes a brownish-gray to gray very fine sand. In uncultivated areas the surface soil may have a dark grayish-brown color. Both soil and subsoil are calcareous.

In topography this type is flat to gently undulating to sloping and drainage is fairly good. The entire type is subject to overflow.

Most of the soil is under cultivation, crops grown and yields obtained being very much the same as on the Sarpy loam. It should be protected from over-

flow if it is to be made satisfactorily productive when used for cultivated crops. It would respond profitably to liberal applications of farm manure or leguminous green manures. It may be somewhat acid in reaction in some cases. When this is true lime should be applied. Phosphorous fertilizers will be needed in the future.

RIVERWASH (53)

There is a very small area of riverwash in the county, amounting to 0.2 percent of the total area. It occurs in numerous small areas in bends or in small islands of the Des Moines and Raccoon rivers.

Riverwash consists of a mixture of fine, medium and coarse sand with some areas of gravel. This soil is not cultivated, owing to the frequency of overflow and the fact that the material is moved about considerably with each rise of the stream. Some of it supports a growth of willow or cottonwood and much is barren.

MUCK AND PEAT (21)

The total area of muck and peat in the county is small, amounting to 0.2 percent of the total area. The areas occur on the flatter uplands in the northern part of the county and along Beaver creek and north of Des Moines. They usually consist of areas from 5 to 15 acres in size, a few of the areas north of Crocker containing 30 to 40 acres.

The surface material of muck and peat consists of 6 to 20 inches of dark brown to black partly decomposed organic matter, derived from the remains of waterloving plants and grasses and with a small mixture of silt, clay or very fine sand washed in from the surrounding land. The surface material is loose and porous when dry but spongy when wet. Some of the material in the areas may be very finely divided and black in color but much of it is only partly decayed and still retains portions of the plant materials from which it has been formed. The underlying material is an impervious clay which is nearly black or dark drab, becoming lighter in color in the lower depths. Both the soil and subsoil are highly calcareous.

Muck and peat occur in small shallow depressions or old ponds and the topography is therefore flat to depressed and the natural drainage very poor. The first treatment needed to make such areas suitable for crop production is the installation of an adequate drainage system. When this is accomplished it is usually most desirable to seed down the areas to a mixture of timothy and alsike utilizing the crop either for hay or as pasture. The latter procedure is somewhat better as the trampling of the stock compacts the surface material and increases the rapidity of decomposition. Occasionally it may be desirable to grow such truck crops as potatoes, cabbage, tomatoes and onions, provided marketing facilities are available. The reclaimed areas near Herrold are utilized in this way and profitable yields of these truck crops are secured. Corn does not do well on newly reclaimed areas of muck and peat and should not be grown for several years after the areas have been drained. Small grain crops are not desirable, as they are apt to lodge. After the muck and peat have decayed for several years then corn and small grains may be grown successfully. Fall plowing is desirable on such areas and deep plowing is likewise desirable in order

that the underlying clay may be opened up to some extent and aid in the making of a satisfactory soil condition. When these areas of muck and peat have been drained and decomposition has proceeded for a few years, large crop yields may be secured, as the natural fertility of the soils is high.

WABASH FINE SANDY LOAM (62)

The Wabash fine sandy loam is of very minor importance in the county, covering only 0.2 percent of the total area. Practically all of it is developed in small areas along the Skunk river.

The surface soil of the Wabash fine sandy loam is a dark brown fine sandy loam, becoming somewhat lighter in color and more compact in the subsoil. The lower subsoil may be a dark brownish-gray or brownish-gray in color. One or two areas along the Skunk river are a gray or dark gray very fine sand 8 to 12 inches in depth overlying typical Wabash clay.

In topography this type is generally sloping and the open nature of the soil material insures adequate drainage. The soil overflows frequently and unless protected cannot be used satisfactorily for cultivated crops. In favorable seasons corn will yield 30 to 50 bushels per acre, but ordinarily crop yields are not satisfactory.

The type is in need of protection from overflow, the application of farm manure, the application of lime, when acid, and the application of phosphorus fertilizers for the continued production of cultivated crops.

SARPY FINE SANDY LOAM (102)

This type is of very minor importance in the county, covering only 0.1 percent of the total area. It occurs in small isolated areas along the Des Moines and Raccoon rivers.

The surface soil of the type is a grayish-brown to brownish-gray fine sandy loam or loamy fine sand extending to a depth of about 14 inches. The subsoil is a grayish-brown, heavy fine sandy loam which at about 27 inches passes into a light grayish-brown loamy fine sand or fine sand. In some areas there is considerable coarse sand and fine gravel thruout the soil section.

In topography this type is flat but the drainage is good. The type is subject to overflow, lying 5 to 15 feet above the normal level of the streams.

Most of the Sarpy fine sandy loam is in cultivation and corn and sorghum are the most important crops. The type is usually included in fields with other soils. Yields are very much the same as on the Sarpy very fine sandy loam. On the uncultivated areas there is only a sparse growth of grass and in some portions practically no vegetation is found. This type is in need of protection from overflow and liberal additions of farm manure, and it will eventually need phosphorus.

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 tyes, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in co-operation with the Bureau of Soils of the United States Department of Agriculture.

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

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

PLANT FOOD IN SOILS

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

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

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

THE "SOIL DERIVED" ELEMENTS

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

AVAILABLE AND UNAVAILABLE PLANT FOOD

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

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

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

REMOVAL OF PLANT FOOD BY CROPS

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

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

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

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

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

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

REMOVAL FROM IOWA SOILS

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

TABLE I. PLANT FOOD IN CROPS AND VALUE

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

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	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

that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

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

PERMANENT FERTILITY IN IOWA SOILS

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

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

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

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help to 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 a lack of the water necessary to bring them their

*Bulletin 150, Iowa Agricultural Experiment Station.

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

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

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

LIMING

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

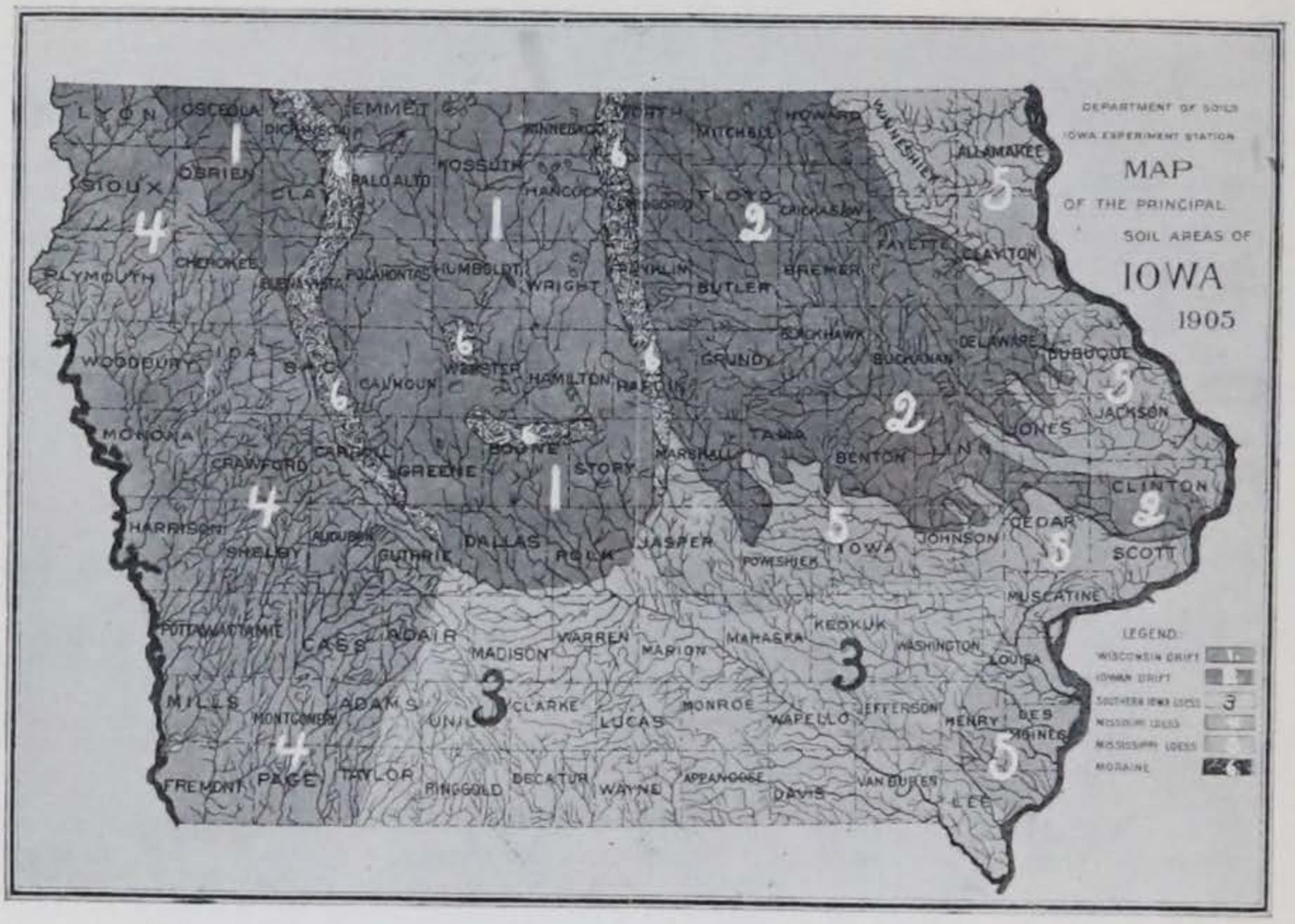

Fig. 10. Map showing the principal soil areas in Iowa

tests of many representative soils reported in bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 10.

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

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift 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.

GENERAL SOIL CHARACTERISTICS

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

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1. 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 or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

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

SOILS GROUPED BY TYPES

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

Peats—Consisting of 35 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.

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

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

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

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

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

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

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

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

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

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

Gravels—More than 50 percent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

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

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

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

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

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

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

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

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