SOIL SURVEY OF IOWA

MAHASKA COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 29
March, 1923
Ames, Iowa

IOWA AGRICULTURAL EXPERIMENT STATION

PUBLICATIONS DEALINGS WITH SOIL INVESTIGATIONS IN IOWA

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151 Soil Acidity and the Liming of Iowa Soils.*
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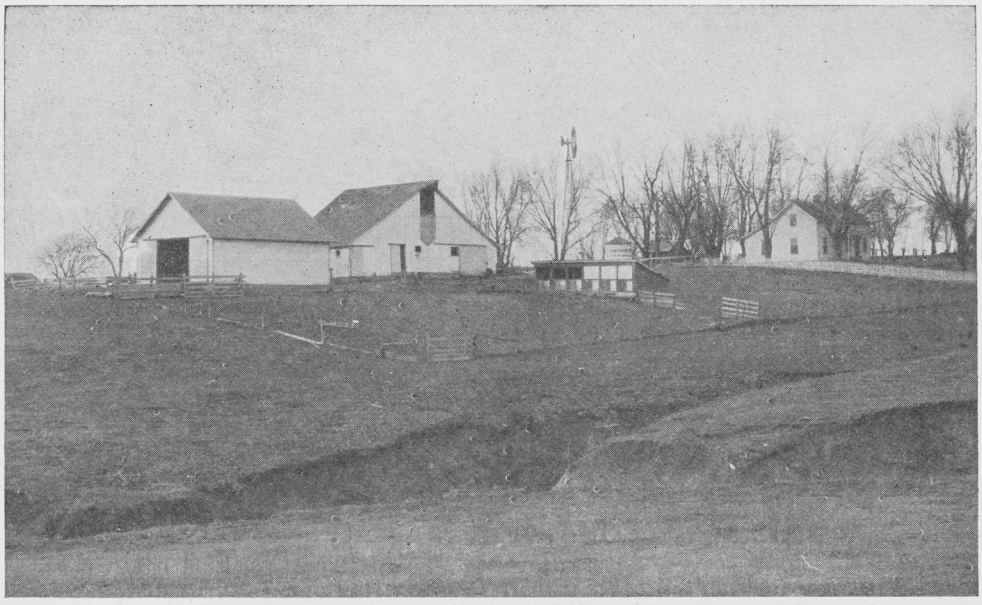
SOIL SURVEY OF IOWA

Report No. 29—MAHASKA COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman and J. A. Elwell



Typical Mahaska county farmstead

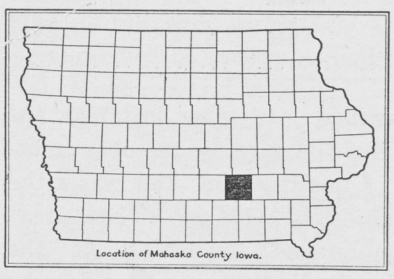
IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

CONTENTS

MAHASKA COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman and J. A. Elwell

MAHASKA COUNTY is located in southern central Iowa in the third tier of counties north of the Missouri state line and in the fourth tier west of the Mississippi river, as shown in the accompanying map. It lies entirely within the Southern Iowa loess soil area and hence the soils of the county are mainly of loessial origin. There is only one type derived from glacial material and that has been formed by the washing away of so much of the surface covering of loess that the drift material makes up most of the three-foot soil section.



The location of Mahaska county.

The total area of Mahaska county is 568 square miles or 363,520 acres. Of this area 352,332 acres or 96.9 percent is in farm land. The total number of farms is 2,921 and the average size of the farms is 121 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1921 show the utilization of the farm land in the county.

Acreage in general farm crops	201,430
Acreage in pasture	120,949
Acreage in farm buildings, feed lots and public highways	13,729
Acreage in waste land	6,077
Acreage in crops not otherwise listed	898

THE TYPE OF AGRICULTURE IN MAHASKA COUNTY

The type of agriculture commonly followed in Mahaska county at the present time is general farming. It includes, therefore, the raising and feeding of livestock and the growing of hay and grain crops. Dairying is practiced to some extent but is not yet a very important industry commercially. The income on the farms is secured chiefly from the sale of livestock and the surplus corn, small grain and forage crops produced. Additional income is provided in some cases from the dairy products and from the sale of poultry and poultry products. The livestock industry is increasing and cattle feeding is becoming more important in the county. With this increase in cattle feeding and the even greater increase in the practice of hog raising, there is occurring a gradual decrease in the amount of the various crops which are sold to outside markets. The income from the dairy industry is increasing and there are now several creameries in operation in the county. Sheep raising is becoming more important and is providing considerable income on many farms. Fruit growing is practiced to some extent, but not on a commercial scale.

The area of waste land in the county is considerable and much of this land may be brought under cultivation and made quite as productive as the sur-

*Soil Survey of Mahaska County, Iowa, by E. C. Hall of the U. S. Department of Agriculture and J. A. Elwell of the Iowa Agricultural Experiment Station.

TABLE I. ACREAGE YIELD AND VALUE OF CROPS GROWN IN MAHASKA 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	120,000	34.05	44.0	5,280,000	$0.30	$1,584,000
Oats	53,000	15.04	22.0	1,166,000	0.23	268,180
Winter wheat	6,500	1.84	21.0	136,500	0.90	122,850
Spring wheat	520	0.14	14.0	7,280	0.87	6,433
Barley	200	0.06	23.0	4,600	0.42	1,932
Rye	130	0.04	22.0	2,860	0.73	2,087
Potatoes	600	0.17	69.0	41,400	1.40	57,960
Tame Hay	20,100	5.70	1.4	28,140	9.08	255,511
Wild Hay	290	0.08	1.2	348	7.47	2,599
Alfalfa	90	0.02	3.75	338	12.92	4,366
Pasture	120,949	34.32	.....	.....	.....	.....

rounding territory if the soils are properly handled. In some instances the areas are in need of drainage and the installation of tile may be the only treatment necessary to bring the soil to a high state of fertility. In other cases the areas occur on the bottoms and are, therefore, subject to overflow. These areas may sometimes be reclaimed thru the straightening and deepening of the stream channels and subsequent drainage. They will then yield good crops in normal seasons. Some areas in the county consist of rather rough, broken land where the topography is steep and the soil is residual in origin. These areas are suitable only for pasture purposes, and sometimes not even for that. There are still other causes of infertility in soils and in a later section of this report special treatments will be suggested which are particularly desirable and most effective under individual soil conditions. In special cases for more or less abnormal conditions, advice regarding treatments may be secured from the Soils Section of the Iowa Agricultural Experiment Station.

THE CROPS GROWN IN MAHASKA COUNTY

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

Corn is the chief crop grown and it occupies the largest acreage and has the greatest value. In 1921, 120,000 acres, over one-third of the county, were devoted to this crop. Average yields secured amounted to 44 bushels per acre, but in many instances with favorable seasonal and soil conditions, yields are very much larger. Much of the corn produced on the farms is utilized for feed and the amount sold out of the county is decreasing as the livestock industries increase in importance. There are 213 silos in the county and a rather considerable amount of the corn produced is used for silage. The principal varieties grown are Reid's Yellow Dent, K. B. Yellow Dent, and Boone County White. Other varieties include Iowa Silver Mine, Johnson County White and Silver King. The corn is grown on sod or oat stubble and the land is usually plowed in the late summer or fall and disked in the spring. Cultivation is practiced three to five times, depending upon the seasonal conditions. Most of the crop is husked by hand. Some is cut and shocked in the field to be fed from the

*Iowa Yearbook of Agriculture, 1921.

stalk or shredded; some is used for ensilage. Occasionally rape or cowpeas are seeded in the corn at the last cultivation and "hogged down" in the fall. This practice is of considerable value in building up the fertility of the soil.

Oats rank second in acreage and value and they are grown on practically every farm. In 1921, over 15 percent of the farm land in the county was devoted to this crop and average yields of 22 bushels per acre were secured. Much larger yields than this are secured under favorable soil conditions when the seasonal conditions are most satisfactory. The varieties commonly grown are the Iowa 103, Swedish Select, Early Champion and Kherson. The Iowa 103 oat has been found to be the most desirable variety for the county. The land is usually prepared for oats by disking and harrowing. Occasionally, however, it is plowed. The larger portion of the crop is used for feed and the straw serves for roughage and bedding. The surplus of oats is sold but the total amount sold out of the county is not large.

Hay is produced on a considerable area in the county and constitutes an important crop. Over 5 percent of the farm land is utilized for the production of tame hay which includes timothy, clover, bluegrass and other grasses. Average yields of the tame hay amount to 1.4 tons per acre. Some timothy is grown alone for seed and occasionally clover is grown for seed. They are sown in the spring with oats. Sometimes clover is utilized for pasture the first year and the second year the first crop is cut for hay and the second utilized for seed. Bluegrass grows well in the county and is used extensively for pasturage. Only a very small area is in wild hay and the amount produced is of little value.

Wheat, which is the next crop in value, is produced on a rather small acreage, amounting to less than 2 percent of the farm land in the county. Both winter wheat and spring wheat are grown, the area in the former being very much larger. Average yields of the winter varieties amount to 21 bushels per acre, while the spring varieties yield about 14 bushels per acre. The variety of winter wheat grown is Turkey, and spring varieties include Early Java, Bluestem and Marquis. Most farmers sell the entire wheat crop.

Potatoes are grown on most farms in the county and the total value of this crop is considerable. Early Rose, Early Ohio and Rural New Yorker are the main varieties produced. Practically all of the potatoes grown are utilized for home consumption.

Alfalfa is grown only on a small acreage at the present time, but it is becoming a more popular crop as farmers learn more of the methods of handling it and appreciate its value. Average yields of alfalfa are large and when the soils are limed, the crop inoculated, good seed used and the seed bed put in good condition, satisfactory yields of alfalfa may be secured on the main upland soils of the county.

Barley and rye are grown on small areas in the county and are of minor importance. Watermelons, muskmelons, cantaloupes, pumpkins and squash are grown on many farms for home consumption. Other crops of less importance are broom corn, peanuts, buckwheat, sweet potatoes, millet, rape and sorghum.

Fruit growing is not carried on in a commercial way, but there is a rather large acreage devoted to the production of fruit for local use. The principal

varieties of apples grown are Baldwin, Jonathan, Willow Twig, Grimes, Ben Davis, Wealthy and Northwestern Greening. Cherries, strawberries, grapes, raspberries and blackberries are grown on small areas and are utilized for home consumption and for sale on the local markets.

MAHASKA'S LIVESTOCK INDUSTRY IS LARGE

The livestock industry of the county consists mainly of cattle feeding, cattle raising, hog raising and feeding, sheep raising and the raising of horses and mules. The following figures taken from the Iowa Yearbook of Agriculture for 1921 show the livestock industries of the county:

Horses, all ages	13,491
Mules, all ages	1,619
Swine, on farms July 1, 1921	126,672
Swine, on farms Jan. 1, 1922	101,733
Cattle, cows and heifers kept for milk	10,342
Cattle, other cattle not kept for milk	27,392
Cattle, all ages	37,734
Sheep, all ages on farms Jan. 1, 1922	18,399
Sheep, shipped in for feeding, 1921	1,476
Sheep, total pounds wool clipped	126,583
Poultry, total number on farms Jan. 1, 1922	378,560
Poultry, number dozen eggs received 1921	1,712,171

Hog raising and feeding is perhaps the most important of the livestock industries in the county. Nearly every farmer feeds from 20 to 50 hogs and on the larger farms several hundred are raised each year. The principal breeds are the Duroc Jersey, Poland China, Chester White, Hampshire, Berkshire and Tamworth. The hogs are shipped to the packing plants at Ottumwa, Chicago, Minneapolis or Des Moines. The income from the sale of hogs is in excess of that from any of the other livestock industries. Cattle feeding is becoming of increasing importance thruout the county, and it is practiced to some extent on nearly all farms. The main breeds are the Angus, Hereford and Shorthorn. There are also many grades of these and other breeds. Cattle raising is practiced to some extent, and is particularly desirable on farms which include some of the rough land in the county. Sheep raising is becoming a rather important industry and increases the income of many farms. The Shropshire is the leading breed. Draft horses are raised on some farms, the Percheron being the most popular. Mules are raised in a few instances. Recently more attention has been given to the poultry industry; and while most farms raise enough poultry to supply the home demand, there has been an increasing sale of poultry and poultry products which adds materially to the income on many farms. Practically all of the eggs produced are sold in the local markets.

The value of land in Mahaska county is extremely variable, depending on the location with reference to railroad and market facilities and on the improvements on the farm, natural soil and topographic conditions. The average price of farm land at the time of the survey, 1919, ranged from $50 to $500 per acre. The latter figure represented a rather abnormal price for the best upland soils at the time of the survey. At present the upland soils will sell for $250 to $300 per acre. The poorer land and low-lying areas are of course, sold at lower figures.

CROP YIELDS HAVE BEEN QUITE SATISFACTORY

The yields of general farm crops in Mahaska county, as shown by the figures given earlier in this report, have been quite satisfactory, particularly on the upland soils. There are many cases, however, where more profitable yields might readily be secured thru the adoption of better methods of handling the soils. In some cases drainage conditions are not entirely satisfactory, and when this is true tile should be installed if profitable crop yields are to be secured. In a few instances the soils are subject to serious washing and the adoption of methods of control of erosion are very necessary if satisfactory yields are to be accured and the soils kept fertile. On the rougher areas the land should probably be kept in pastures in order to prevent erosion.

MOST OF MAHASKA COUNTY SOILS ARE ACID

Practically all of the soils in the county are acid in reaction and applications of lime are necessary if satisfactory crop yields, particularly of legumes, are to be secured. There is no lime present in any of the surface soils on the uplands and only in one case is there lime in the lower soil layer and in that one instance the amount of lime present is small and the type will soon be in need of liming. Most of the bottomland soils are likewise acid in reaction and only in two cases is there any indication that lime is not needed. All of the upland soils in the county, therefore, and most of the bottomland types, should be tested for lime requirement. This material should be applied in the proper amounts if satisfactory crops are to be secured. Tests are necessary at regular intervals and the application of lime when needed is made preferably preceding the legume crop of the rotation.

The soils of the county in general are not very well supplied with organic matter and neither are they strikingly deficient. The Knox fine sand is very low in organic matter, as is also the Sarpy fine sandy loam on the bottoms. The majority of the upland types, however, are fairly well supplied with organic matter and dark in color.

The application of farm manure is of large value on all the soils of the county. Even the darker colored, apparently richer soils seem to be made more productive when farm manure is applied. On the light colored soils heavier applications of manure prove distinctly profitable. The beneficial effects of manure make its use desirable on all the soils and there is very little danger of making too large an application. Only on the Grundy soils should precaution be taken to apply the manure in smaller amounts, and at points in the rotation other than preceding the oats crop, to avoid the danger of lodging. The proper use of manure will aid materially in keeping up the organic matter content of the soils. All crop residues should also be used for this purpose and where farm manures are not available in sufficient amounts, leguminous crops should be utilized as green manures to maintain the supply of organic matter. By the proper use of farm manures, leguminous green manures and crop residues, the nitrogen content of the soils, as well as the organic matter supply, may be maintained much more readily.

PHOSPHORUS CONTENT OF SOILS IS LOW

The phosphorus content is low in practically all the soils in the county and hence it is evident that phosphorus fertilizers, if not of value at the present time, will certainly be needed in the near future. There are many instances when phosphorus would probably prove of value on the soils of this county, and the greenhouse experiments and field tests on similar types in other counties indicate that profitable returns may frequently be secured from the use of phosphorus fertilizers. Farmers are urged to test rock phosphate and acid phosphate on their own soils at the present time in order to choose that material which will give the best returns. Field experiments now under way will permit of the making of a choice between these two materials in the future, but at present definite results can only be secured by tests on the individual farm.

THE GEOLOGY OF MAHASKA COUNTY

The native rock material underlying the soils of Mahaska county is buried under heavy deposits of glacial drift and loess and so rarely is there any exposure of these rocks that they have practically no effect upon the soil conditions of the county. There is only one soil derived from this bedrock material, and this type is known as the Union silt loam. It occurs only in narrow strips along deep drainageways, ravines, and the steep slopes, where the surface covering of drift and loess have been almost entirely washed away. The type is of practically no significance agriculturally.

During the glacial age a great sheet of ice known as the Kansan glacier spread over the entire area of the county and, upon its retreat, left behind a deposit of glacial debris or drift varying in depth from a few feet to several hundred feet. This Kansan drift is composed of bluish, gritty clay, sand, gravel and boulders. Originally it was a bluish-drab in color, but thru aeration and oxidation, this color has been changed to yellow or brown. Small boulders are found commonly thruout the drift deposit. The only soil type in the county which is derived from this Kansan drift is called the Lindley silt loam. It occurs where the loessial covering has been partially washed away along steep slopes and bordering deep valleys. The type is composed of a thin layer of loess, with the drift material making up a large part of the soil section.

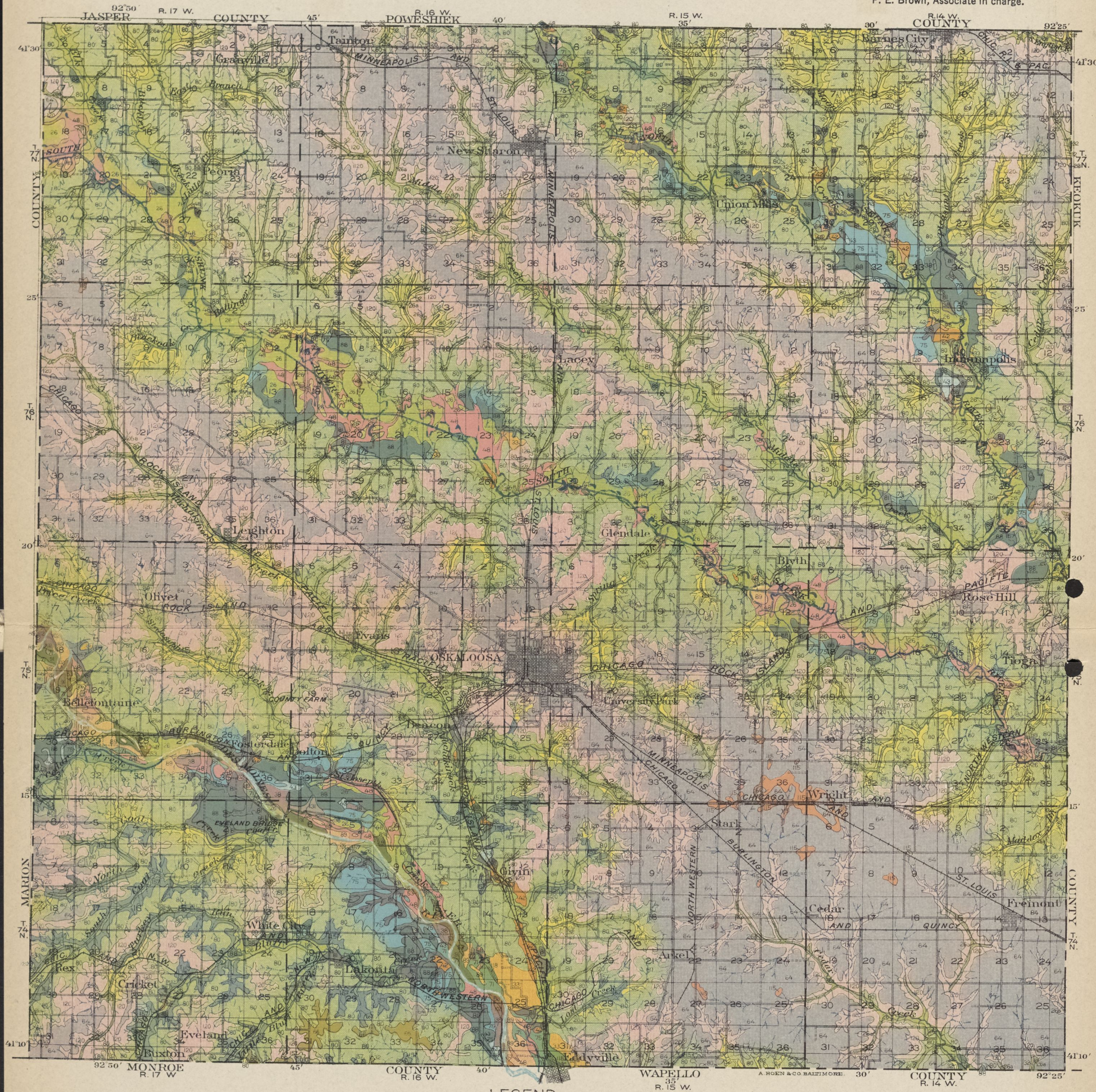
At some later geological time, a covering of wind-blown material known as loess was laid down over the entire surface of the county. The original depth of this silty material varied from 10 to 20 feet and it contained about 75 percent silt. It ranges in color from a light grayish-brown to yellowish-brown in its unchanged condition. After it has been exposed to weathering and to the accumulation of organic matter thru a long period of time, the color has become darker and ranges from a yellow to a dark brown or black. The original content of lime and other soluble salts has been washed away and there has been some accumulation of finer clay particles from the surface in a subsurface layer, and a still greater accumulation in the subsoil. Much of the glacial covering has been washed from the surface of the land and the depth of the loess mantle ranges now from a few inches to about 12 feet, depending to a large extent upon the topographic condition. The Grundy, Tama, Clinton and

SOIL MAP OF MAHASKA COUNTY

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

Thomas D. Rice, Inspector, Northern Division.
Soils surveyed by E. C. Hall, of the U. S. Department of Agriculture, in charge, and J. Ambrose Elwell of the Iowa Agricultural Experiment Station.

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



LEGEND

DRIFT SOILS

32	Lindley silt loam

LOESS SOILS

80	Clinton silt loam
120	Tama silt loam
64	Grundy silt loam
33	Knox fine sand
115	Grundy silty clay loam
66	Putnam silt loam

TERRACE SOILS

88	Bremer silt loam
75	Waukesha silt loam
81	Jackson silt loam
42	Calhoun silt loam
43	Bremer silty clay loam
38	Buckner loam
131	Judson silt loam
118	Plainfield loamy fine sand

SWAMP AND BOTTOMLAND SOILS

26	Wabash silt loam
26a	Wabash silt loam (colluvial phase)
48	Wabash silty clay loam
71	Genesee silt loam
89	Sarpy silt loam
91	Sarpy loam
102	Sarpy fine sandy loam
53	Riverwash

RESIDUAL SOIL

157	Union silt loam

Scale: 1 inch = 2½ miles

A. HOEN & CO. BALTIMORE.

Putnam soils, which together cover by far the largest portion of the upland area in the county, are all derived from loess. In the Clinton and Tama soils, oxidation has been more complete and uniform and hence the subsoil characteristics are quite different. The Grundy, Tama, and Putnam series have been developed under prairie conditions and the content of organic matter has been derived from the heavy growth of grasses. The lighter colored soils of the Clinton series have been developed along stream borders under a forest of oak and hickory, hence, contain much less organic matter.

The terrace and bottomland soils of the county are made up chiefly of loessial material carried down by the streams and surface wash and deposited along the streams at times of overflow. The terraces have been modified thru weathering since their deposition and have been raised above overflow by a deepening of the river channel, or a decrease in volume of water carried by the stream. Those which have been above overflow for a longer period of time and have therefore undergone more oxidation in the lower soil layers, giving them a brown color, are included in the Waukesha, Buckner, Jackson, Judson and Plainfield series. The more recently formed and still poorly drained terraces are included in the Bremer and Calhoun series. Their subsoils are very dark in color and contain many mottlings, indicating poor oxidation conditions. The bottomland soils are subject to overflow and are modified at more or less irregular intervals by new deposits from the streams. These soils are classed in the Wabash, Sarpy and Genesee series, the Wabash and Genesee soils being characterized by heavy subsoils while the Sarpy soils typically contain a sandy or gravelly subsoil. Along many of the small streams the bottomland soil has been partially covered and much modified by the washing down of soil material from the slopes. These areas are mapped as the colluvial phase of the Wabash silt loam.

PHYSIOGRAPHY AND DRAINAGE

The topography of Mahaska county as a whole is gently rolling to rolling. The whole surface of the county slopes gradually from the northeast to the southwest. The original level plain of the county has been cut by three large streams and three smaller streams flowing at right angles to the slope of the surface. A series of four ridges, representing the remains of the original upland prairie, stretch across the county from the northwest to the southeast.

The first of these ridges is in the northeastern part of the area. The North Skunk river has cut thru the original prairie, from the southwest boundary of this ridge. The ridge extends out of the county north and east and is bounded in that direction by the Iowa river and the Des Moines river. The north side tributaries of the North Skunk river have brought about much greater erosion on that side of the stream, while on the south side, the stream borders are less rough.

The second ridge or plateau lies between the North Skunk river and the South Skunk river in the north central part of the county. This has been cut in the northwestern part of the county by Buckley creek and its tributaries. The remainder of the plain has been cut by Middle creek into two almost equal

parts, leaving remains of the original plain on each side, that to the north having a somewhat greater elevation.

The third plain or ridge occurs between the South Skunk river and the Des Moines river, extending diagonally across the south central portion of the county. This plain is cut by Muchakinock creek and its tributaries and in the extreme southeastern portion by Cedar creek. In this part of the area the surface plain is smoother and more prairie-like and the topography adjoining Cedar creek is not so rough as that adjacent to Muchakinock creek.

The fourth ridge is in the extreme southwestern part of the county south of the Des Moines river and this is cut by the North Coal, South Coal, Turkey Run and Bluff creeks, tributaries of the Des Moines river, flowing in a northeasterly direction.

The topography in the southwestern section of the county is quite rough and broken and corresponds more closely to the topographic condition in the northeastern portion of the area. The plains in between have been eroded to a small-

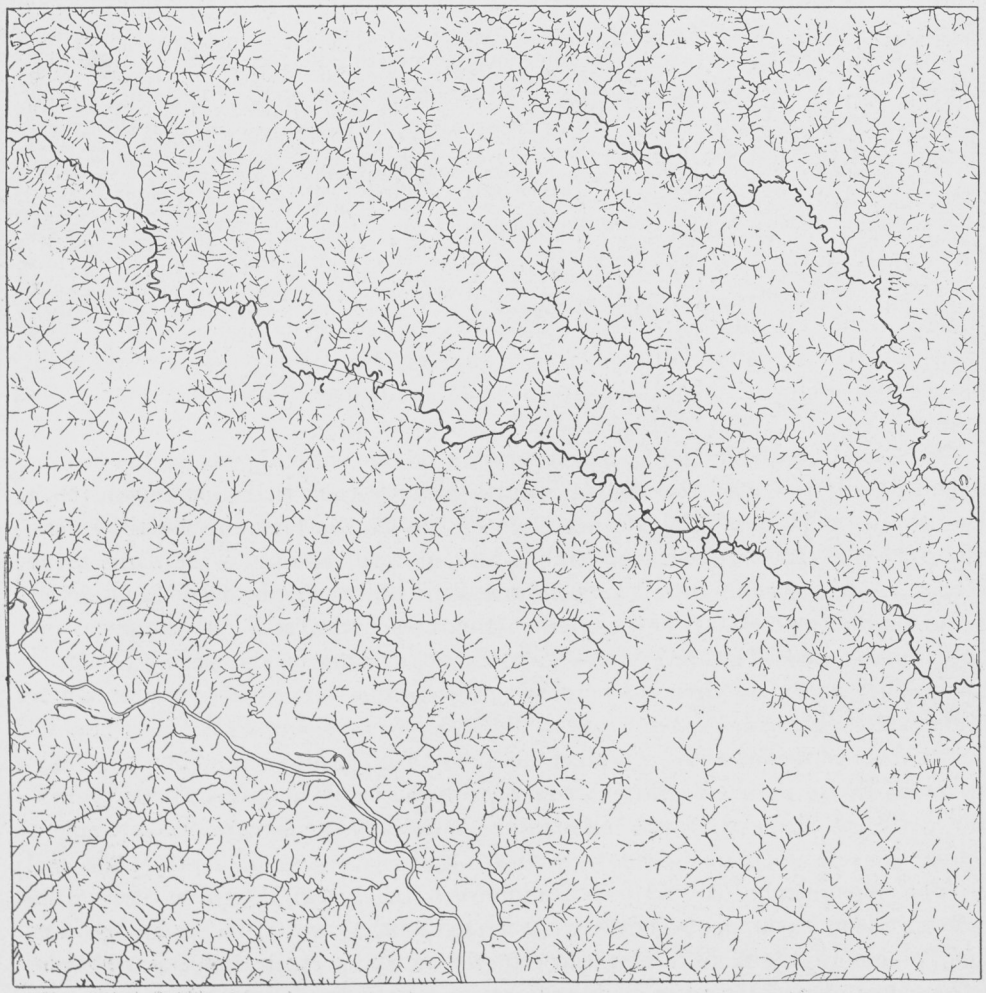


Fig. 1—Map showing natural drainage system of Mahaska county.

er extent and the topography is more or less rolling to gently rolling. The northwestern portion of the county, particularly in Richland township, resembles more closely the topographic features in the southwestern and northeastern sections and is distinctly rough. In the southeastern part of the county the topography is smoother and more gently rolling. The slopes are long and gentle and the divides between the streams are broader. In general the topographic features of Mahaska county vary from steep, broken and hilly in places to rolling or gently rolling thruout the major portion of the upland plains.

The drainage of the county is brought about by the North Skunk river, the South Skunk river, the Des Moines river and their tributaries. The North Skunk river crosses the county in the northeastern part and the chief tributaries are Buck creek, Moon creek, Pleasant creek, Cedar creek and Middle creek, the latter flowing diagonally across the county, almost parallel to the river and joining it almost at the county line. The valley of this river is comparatively wide, averaging about three-fourths of a mile in width. The tributaries flow thru narrow bottomlands and are bordered by much wider belts of eroded upland.

The South Skunk river, the second largest stream in the area, flows southeasterly across the county entering from the west at a point three miles south of the northern county line. It is approximately 43 miles in length in the county, but the course of the river is now being straightened from the Marion county line to a point about one-fourth mile north of the Chicago, Rock Island and Pacific railway bridge between Oskaloosa and Rose Hill which will shorten the length of the river considerably. The bottomland along this river varies from one-fourth mile to one and three-fourths mile in width, averaging about three-fourths of a mile to one mile. The largest tributaries of the South Skunk river are Buckley and Ballinger creeks and Maddox Branch. This river with its tributaries brings about the drainage of the entire central portion of the county.

The Des Moines river is the largest stream in the county, crossing the county diagonally in the southwestern townships, passing thru Scott, Jefferson, East Des Moines and West Des Moines townships. The bottomland along the Des Moines river varies from three-fourths mile to two miles in width, averaging about one and one-fourth miles. The largest tributary of the Des Moines river is Muchakinock creek. Other important tributaries are Cedar, St. Joseph, Bluff and Coal creeks. This river with its tributaries brings about the drainage of the southwestern portion of the county. The southeastern corner is drained by Cedar creek.

The natural drainage system of Mahaska county is quite complete. The larger streams with their tributaries extend into practically all parts of the county. With the exception of Cedar creek in the southeastern part, practically all of the streams have cut deep valleys and are still increasing in depth. The Des Moines river channel is 100 to 175 feet lower than the upland plain while the North and South Skunk rivers have channels from 90 to 150 feet below the upland plain. There is sufficient flow, therefore, to carry drainage water from the upland areas between the various streams and only in a few instances is

there any necessity for the installation of artificial drainage. The southeastern corner of the county which is more level and less well drained, contains several areas of Grundy silty clay loam which is a poorly drained soil. There are some areas in the Grundy silt loam on the upland in various parts of the county that would be benefitted by tiling. The Calhoun silt loam, Bremer silt loam and Bremer silty clay loam on the terraces are frequently in need of artificial drainage and the Wabash soils of the bottoms may occasionally be benefitted by artificial drainage.

THE SOILS OF MAHASKA COUNTY

The soils of Mahaska county are grouped into five classes according to their origin and location. These are drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils. Drift soils are formed from materials carried by glaciers and deposited on the surface of the land when the glacier retreated. Loess soils are fine dustlike deposits made by the the wind at some time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them or by a deepening of the river channels. Swamp and bottomland soils are those occurring in poorly drained areas and along streams, and are subject to more or less frequent overflow. Residual soils are formed from the underlying rock material and remain resting upon it. The extent and occurrence of these groups of soils are shown in table II.

By far the largest portion of the county is covered by the loess soils, 76.9 percent. There is only one drift soil and it is of minor importance, covering 4.0 percent of the total area. The terrace soils are more extensive, the total area included in these soils amounting to 5.0 percent of the county. Swamp and bottomland soils occur more extensively and cover 12.9 percent of the county. There is one residual soil, covering 1.2 percent of the total area.

There are 22 individual types in the county and these together with the colluvial phase of the Wabash silt loam and riverwash make a total of 24 separate soil areas. There is one drift soil, six loess soils, eight terrace types, eight areas of swamp and bottomland soils, and one residual soil. These various soil types are distinguished on the basis of certain definite characteristics, which are described in the appendix of this report. The areas of the various soil types are given in table III.

The Clinton silt loam is the largest individual soil type in the county as well

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

Soil Group	Acres	Percent of total area of county
Drift soil	14,848	4.0
Loess soils	279,360	76.9
Terrace soils	18,240	5.0
Swamp and bottomland soils	46,528	12.9
Residual soils	4,544	1.2
Total	363,520	

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

Soil No.	Soil Type	Acres	Percent of total area of county
	DRIFT SOIL		
32	Lindley silt loam	14,848	4.0
	LOESS SOILS		
80	Clinton silt loam	121,472	33.4
120	Tama silt loam	81,344	22.4
64	Grundy silt loam	73,728	20.3
33	Knox fine sand	1,216	0.3
115	Grundy silty clay loam	1,024	0.3
66	Putnam silt loam	576	0.2
	TERRACE SOILS		
88	Bremer silt loam	7,296	2 0
75	Waukesha silt loam	5,248	1.4
81	Jackson silt loam	3,008	0.8
42	Calhoun silt loam	896	0.2
43	Bremer silty clay loam	640	0.2
38	Buckner loam	640	0.2
131	Judson silt loam	256	0.1
118	Plainfield loamy fine sand	256	0.1
	SWAMP AND BOTTOMLAND SOILS		
26	Wabash silt loam	25,088)	9.2
26a	Wabash silt loam (colluvial phase)	8,320)	
48	Wabash silty clay loam	7,040	1.9
71	Genesee silt loam	2,816	0.8
89	Sarpy silt loam	2,048	0.6
91	Sarpy loam	576	0.2
102	Sarpy fine sandy loam	320	0.1
53	Riverwash	320	0.1
	RESIDUAL SOIL		
157	Union silt loam	4,544	1.2
	Total	363,520	——

as the largest loess soil, covering one-third of the total area, 33.4 percent. The Tama silt loam is the second largest soil type and the second most extensive loess soil, covering 22.4 percent of the county. The Grundy silt loam is slightly smaller, covering 20.3 percent. The three remaining loess soils are all very minor in extent, covering less than one-half percent of the total area. The Lindley silt loam, the only drift soil in the county is minor in area, covering 4.0 percent. The terrace soils are all small in extent, the Bremer silt loam, the largest, covering but 2.0 percent. The Waukesha silt loam which is next, covers 1.4 percent. The remaining types are all small in area. The Wabash silt loam, the largest bottomland soil, together with the colluvial phase, which is much less extensive, covers 9.2 percent. The Wabash silty clay loam, the second largest bottomland soil, covers 1.9 percent. The remaining types are all small in area and cover less than 1 percent of the county. The Union silt loam, the only residual soil in the county, covers 1.2 percent of the area.

The topographic features of the uplands of the county are rather closely related to the soil types occurring on them. The Lindley silt loam is characterized by a steep to broken topography. The Clinton silt loam occupies rolling to rough areas and only infrequently occurs in level areas. The Grundy soils are more level, and the silty clay loam is found in flat or almost depressed areas. The Knox fine sand is rough in topography while the Putnam soils oc cur on more level areas in association with the Grundy soils. The terrace soils

are all rather level in topography but the soils of the Bremer and Calhoun series are more depressed than the soils of the Buckner, Judson, Jackson and Waukesha series. The bottomland soils are all level in topography and the types of the Wabash series are particularly in need of drainage. The Union silt loam, the only residual type in the county is found on very rough broken land and presents the most striking topographic features.

THE FERTILITY OF MAHASKA COUNTY SOILS

Samples were taken for analyses from each of the soil types in Mahaska county, except the areas of Plainfield loamy fine sand, Union silt loam and riverwash. The first two of these soils are of such minor occurrence and so unimportant agriculturally, that they were not sampled for analyses. Riverwash is so variable in composition that analyses would mean practically nothing. The more extensive soil types were sampled in triplicate but only one sample was taken in the case of the minor types. The samples were all taken with the utmost care that they should represent the particular soil types and that variations due to local conditions and previous treatments should be eliminated. Samples were drawn at three depths, 0 to 6 2-3 inches, 6 2-3 to 20 inches, and 20 to 40 inches, representing the surface soil, the subsurface soil, and the subsoil respectively.

The total phosphorus, total nitrogen, total organic carbon and inorganic carbon content of the soils were determined and the limestone requirement was also estimated. The determinations of phosphorus, nitrogen, and carbon were made according to the official methods. The Truog qualitative test was used in determining the limestone requirement. The figures given in the tables are the average of the results of duplicate determinations on all samples of each type. They represent, therefore, the averages of four or twelve determinations.

THE SURFACE SOILS

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

There is a rather wide variation in the total phosphorus content of the various soil types in the county, the amount present ranging from 660 pounds in the Lindley silt loam and the Jackson silt loam up to 2195 pounds in the Sarpy loam. No definite relations are apparent between the phosphorus content of the soils and the various soil groups, altho the average of the bottomland types is somewhat higher than that for the other groups. This might be expected inasmuch as the bottomland soils have been cropped to a less extent and there has been less removal of the element. The terrace soils average slightly higher than the loess types but the difference is not great. There is only one drift soil in the county, the Lindley silt loam and this is very low in phosphorus, as has been noted. No comparisons could be made because no other drift types were found. There are some rather wide variations within the various soil groups and in fact, these variations are somewhat greater than the variations between groups.

There is some relation evident between the phosphorus content of the individual soils and the soil series or particular type, thus the Clinton and Putnam

TABLE IV. PLANT FOOD IN MAHASKA COUNTY, IOWA, SOILS

Pounds per acre of two million pounds of surface soil (0-6 2-3″)

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone Requirement
	DRIFT SOIL					
32	Lindley silt loam.....	660	2,120	27,846	0	3,000
	LOESS SOILS					
80	Clinton silt loam.....	982	2,200	31,158	0	3,333
120	Tama silt loam	1,107	3,526	45,718	0	5,666
64	Grundy silt loam.....	1,279	4,486	70,634	0	5,666
33	Knox fine sand	942	720	10,592	0	6,000
115	Grundy silty clay loam..	1,320	5,480	78,078	0	2,000
66	Putnam silt loam	969	2,840	34,944	0	6,000
	TERRACE SOILS					
88	Bremer silt loam.....	1,266	4,360	54,054	0	6,000
75	Waukesha silt loam	1,508	4,020	53,671	0	6,000
81	Jackson silt loam	660	2,400	29,721	Trace	0
42	Calhoun silt loam.....	1,589	4,300	52,470	0	5,000
43	Bremer silty clay loam..	1,630	3,640	47,338	0	6,000
38	Buckner loam	1,144	1,440	19,926	0	2,000
131	Judson silt loam	1,414	3,620	49,140	0	6,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,736	3,020	38,493	0	2,000
26a	Wabash silt loam (colluvial phase)	1,293	5,260	71,526	0	6,000
48	Wabash silty clay loam..	1,454	3,740	48,539	0	2,000
71	Genesee silt loam	1,817	3,360	37,947	0	4,000
89	Sarpy silt loam	1,481	2,620	29,983	920	0
91	Sarpy loam	2,195	2,000	22,700	1,760	0
102	Sarpy fine sandy loam...	942	720	9,445	0	2,000

silt loams are lower in phosphorus than the Tama and Grundy soils. The Bremer and Waukesha soils on the terraces are higher than the Buckner and Jackson soils. The Wabash soils are ordinarily richer than the Sarpy soils but the Sarpy loam in this county or at least the sample taken contained more phosphorus than any of the Wabash samples. Most of the soils are silt loams and hence comparisons of the phosphorus content of soils of different texture are not possible except in a few instances. The Grundy silty clay loam is higher than the Grundy silt loam and the Bremer silty clay loam contains more phosphorous than the Bremer silt loam, but the Wabash silty clay loam is not as well supplied as the silt loam. In general it would be expected that the silty clay loams would be richer than the silt loams. The Sarpy fine sandy loam is lower in phosphorus than the other soils of the same series. The loam seems to be higher than the silt loam, but as noted above this seems to be a somewhat abnormal soil. Ordinarily the silt loam would be richer than the loam. The Knox fine sand on the upland is lower in phosphorus than would be expected and in general the results seem to indicate that coarse textured soils are not usually as well supplied with phosphorus as is the case with the finer textured soils. This is true when soils of different textures in the same series are concerned, and very often it is the case also when soils in different series are compared. Some soil series are so entirely different in characteristics from others, that comparisons between series should not be made without giving rather definite information regarding the characteristics of the series involved.

In general the results seem to indicate that the phosphorus supply in the soils of Mahaska county is not large in any case. While it is not strikingly deficient in some instances, in practically all cases the supply is too low for a continued production of available phosphorus sufficient to keep crops supplied for more than a very few years. It is quite evident that phosphorus fertilizers should give beneficial effects at the present time in many cases.

The total supply of phosphorus in soils does not indicate how much will be made available for crop use in any one season but when the total amount is low it may be rather positively concluded that there will be an insufficient production of the element in an available form. If the supply is large there is more chance for an adequate production of available phosphorus, but the amount produced cannot be determined definitely. In the soils of Mahaska county, therefore, where the total content is low, it is very reasonable to conclude that phosphorus fertilizers may be of value in many cases at the present time because of the probable need of available phosphorus. As will be noted later, phosphorus applications have been found to be of value in many instances and while definite recommendations cannot be made at this time, it is urged that farmers test the use of various phosphorus fertilizers on their own soils and thus determine for their own conditions which material would prove the most profitable.

In nitrogen content the soils of the county are even more variable than in phosphorus. The total amount ranges from 720 pounds in the Knox fine sand and the Sarpy fine sandy loam up to 5,480 pounds in the Grundy silty clay loam. There is no relation apparent between the nitrogen content of the various soil groups and the variations within groups are much larger than the variations between groups. The relation of nitrogen content to texture is evidenced in the few instances where the textures of the soils vary. Thus the two types mentioned above, which are the lowest in nitrogen, are a fine sand and a fine sandy loam. The Buckner loam and the Sarpy loam are lower in nitrogen than any of the silt loams which is the predominating texture of the soils in the county. The Grundy silty clay loam is higher than the Grundy silt loam but the reverse is true in the case of the Bremer soils.

There are some interesting relations evident also between the various silt loams. Thus the Grundy and Tama silt loams on the uplands are higher than the Clinton and Putnam silt loams. The Bremer and Waukesha are higher than the Jackson and Judson silt loams on the terraces. The Wabash silt loam contains more nitrogen than the Genesee or Sarpy on the bottoms. These are evidences of the variations in some of the characteristics upon which the differentiation of the soil series is based. There is some relation also between the nitrogen content of the soils and their topographic position. Thus the Grundy and Tama soils on the upland and the Bremer and Waukesha on the terraces are more level in topography than the other types with which they are compared. This topographic condition is another factor upon which the soil series are separated. In general it may be said that soils heavy in texture and level to depressed in topography ordinarily will contain more nitrogen and will be classified in series which include the darker colored soils.

The analyses indicate that the soils of the county with the exception of the two sandy types are fairly well supplied with nitrogen. In spite of this fact, nitrogen must not be disregarded in planning systems of permanent fertility. If the nitrogen content of the soil is to be kept up, some material supplying this element must be applied at regular intervals. Farm manure is the commonest material utilized to maintain nitrogen in the soil and it has a large fertilizing value because of its nitrogen content. Beneficial effects of farm manure are not restricted, however, to the soil types which are lowest in nitrogen but will be evidenced even on those types which are apparently well supplied. While the largest influence will appear on sandy soils considerable crop increases are secured when this material is applied to such types as the Grundy silt loam, Tama silt loam and Grundy silty clay loam. In these cases, however, smaller applications may be made with beneficial effect.

The proper use of crop residues on the farm also aids materially in keeping up the nitrogen content of the soil. When farm manure is not available for use, as on the grain farm or where there is an insufficient production to make applications to all the land on the farm, well inoculated leguminous crops should be utilized as green manures. When well inoculated, legumes make use of the free nitrogen of the atmosphere and hence they may serve to increase the nitrogen content of the soil provided a part or all of the crop is turned under in the soil. If a legume is removed from the soil there will be no increase in nitrogen, as in the average soil the amount of nitrogen contained in the roots of the legumes is about equivalent to that taken from the soil. To keep up the nitrogen content in the soils of Mahaska county, therefore, there should be a thoro utilization of all the farm manure and crop residues and leguminous crops should be turned under as green manures.

The organic carbon content of soils indicates the amount of organic matter present. The color of the soil also indicates the organic matter content. Black soils are high in organic matter, while light colored soils are apt to be lacking in organic matter. Furthermore, there is a definite relation between the organic carbon in soils and the nitrogen present. Hence the color of the soil indicating the organic matter supply will also indicate the supply of nitrogen and vice versa. There is a wide variation in organic carbon in the soils of Mahaska county, the relations between the soil types in content of this constituent being very much the same as in the case of nitrogen. The sands are the lowest and the loams are higher than the sandy types and contain less organic matter than the silt loams. The silty clay loams are occasionally higher than the silt loams. Very similar relations between organic carbon and the individual soil series are shown as were noted in the case of nitrogen and in general, it seems that the soils which are level to depressed in topography and finer in texture are richer in organic matter.

The relation between the carbon and nitrogen in soils indicates quite definitely the rate at which plant food is being made available. There seems to be a rather satisfactory relation between these two constituents in the soils of Mahaska county, altho in some instances the relations are more satisfactory than in others. The beneficial effect of manure is particularly evidenced on those

soils in which the relation is not quite so good. This is due to the fact that manure stimulates bacterial activities and indirectly increases the production of available plant food. Where the carbon-nitrogen relation is not at the best, there will be an insufficient production of available food constituents.

In all the soils of the county the organic matter supply must be maintained. Farm manure, crop residues, and leguminous crops must be utilized for this purpose. None of the soil is extremely high in organic matter and under continued cultivation and drainage there is a constant removal of this material. On the sandy types the supply must be built up by especially large additions of organic materials, while on the other types, normal applications should be made in order to prevent the soils from becoming infertile due to lack of organic matter.

Only two of the soils in the county show any content of inorganic carbon and in neither case is the amount large. These two types, both in the Sarpy series, and the Jackson silt loam, are the only ones which do not show a lime requirement. The amount of lime needed is indicated roughly in the figures given in the table. These figures should not be considered to show definitely the amount of lime which should be applied to any particular soil. Soils vary widely in lime requirement and before an application is made the individual soil should be tested. The figures do serve to show, however, that practically all the soils of the county are acid in reaction and need applications of lime if crop growth, particularly of legumes, is to be satisfactory. Even in those cases where there is a small amount of inorganic carbon, lime will be needed in the future as the amount present in the soil will be washed away rather rapidly. All the soils of the county, therefore, should be tested and lime applied when needed.

THE SUB-SURFACE SOILS AND THE SUBSOILS

The results of the analyses of the subsurface soils and the 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 per acre. The plant food present in the lower soil layers has comparatively little effect on the fertility of the soil unless the amount present is very large. The analyses of the surface soils, therefore, usually indicate fairly definitely the needs of the soil and the conclusions drawn will not be largely modified by a detailed study of the analyses of the lower layers.

The subsurface soils and subsoils of Mahaska county are not rich in any of the plant food constituents, in general they are not as high as the surface soils and hence the fertility of the soils is not affected to any large extent by the subsoil conditions. The analyses of these lower soil layers need not be considered in detail and it may merely be noted that they serve to confirm the conclusions drawn from the results of the analyses of the surface soils. The phosphorus supply is low and phosphorus will be needed in the near future and might probably prove of value in many cases at the present time. The nitrogen and organic matter supply is not low except in one or two instances but the soils will respond to applications of farm manure and this material together with crop residues and leguminous green manures must be utilized if the nitrogen and organic matter supply is to be kept up. There is no large content of lime in the lower soil layers of any of the types and hence it is necessary that the soils be

TABLE V. PLANT FOOD IN MAHASKA 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 SOIL					
32	Lindley silt loam	996	1,440	19,765	0	7,000
	LOESS SOILS					
80	Clinton silt loam	1,687	2,040	23,514	0	5,333
120	Tama silt loam.....	1,805	4,040	51,578	0	5,333
64	Grundy silt loam	1,877	4,453	66,247	0	4,333
33	Knox fine sand.....	1,508	880	16,926	0	5,000
115	Grundy silty clay loam..	2,398	5,920	91,676	480	0
66	Putnam silt loam	1,186	2,320	30,685	0	6,000
	TERRACE SOILS					
88	Bremer silt loam.....	1,912	5,120	67,704	0	6,000
75	Waukesha silt loam.....	1,778	4,240	60,606	0	6,000
81	Jackson silt loam.....	1,186	1,760	20,202	0	5,000
42	Calhoun silt loam.....	1,562	2,240	33,852	0	6,000
43	Bremer silty clay loam..	2,926	4,240	62,790	0	6,000
38	Buckner loam	2,370	3,360	54,927	0	3,000
131	Judson silt loam.....	2,828	6,480	89,544	0	6,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam.....	2,990	6,360	69,888	0	2,000
26a	Wabash silt load (colluvial phase)	1,912	5,600	92,274	0	6,000
48	Wabash silty clay loam..	3,016	6,360	85,722	0	4,000
71	Genesee silt loam.....	2,478	4,240	48,594	0	4,000
89	Sarpy silt loam.....	2,478	4,800	52,894	1,160	0
91	Sarpy loam	2,828	2,800	28,458	480	0
102	Sarpy fine sandy loam...	1,940	1,120	12,012	0	2,000

tested for lime requirement and that this material be applied when they are acid. The types which showed some inorganic carbon in the surface soil contain very similar amounts in the lower soil layers and two other types, the Grundy silty clay loam and the Sarpy fine sandy loam, show a small amount of lime at the lower depths. The supply is too small, however, to be significant and under adequate drainage conditions the amount present will soon be exhausted. All the soils of the county should be tested for lime requirement regardless of any small supply in the subsoil.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Mahaska county in order to gain some indications of the fertilizer needs of the soils and to determine the possible value from the application of certain fertilizing materials. The Grundy silt loam and the Tama silt loam, two of the most important types in the county, were used. In addition, greenhouse experiments on the Clinton silt loam from Wapello county are included, inasmuch as this is a very important type in Mahaska county and the results secured in the other county would indicate very definitely the results which may be secured in Mahaska. Experiments on the Grundy silt loam from Wapello county and on the Tama silt loam from Black Hawk county are also given as these types occur extensively in Mahaska county.

The treatments used in all the experiments include manure, lime, rock phosphate, acid phosphate, and a complete commercial fertilizer. These ma

Fig. 2—Clover pot culture on Grundy silt loam. Lime with manure produced a substantial increase, as did also both the rock and acid phosphates.

terials were applied in the same amounts in which they are used in field experiments and in practice and hence the results of these greenhouse tests may be considered to indicate quite definitely the results which may be secured in the field. Manure was added at the rate of 8 tons per acre, lime in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate was used 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 com-

TABLE VI. PLANT FOOD IN MAHASKA 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 SOIL					
32	Lindley silt loam.....	1,536	840	13,595	0	9,000
	LOESS SOILS					
80	Clinton silt loam.....	2,680	1,940	23,860	0	7,000
120	Tama silt loam.....	2,774	3,500	45,427	0	5,666
64	Grundy silt loam.....	2,438	3,630	48,255	0	1,666
33	Knox fine sand	1,536	1,320	22,113	0	3,000
115	Grundy silty clay loam.	2,547	3,360	50,397	1,200	0
66	Putnam silt loam.....	2,142	3,840	45,700	0	5,000
	TERRACE SOILS					
88	Bremer silt loam.....	1,899	3,180	38,984	0	6,000
75	Waukesha silt loam....	2,466	3,180	39,312	0	6,000
81	Jackson silt loam.....	1,818	2,340	27,027	0	7,000
42	Calhoun silt loam.....	1,980	1,680	33,906	0	5,000
43	Bremer silty clay loam..	3,555	5,700	82,719	0	5,000
38	Buckner loam	3,354	4,860	54,054	0	3,000
131	Judson silt loam.....	3,432	7,200	103,849	0	6,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam.....	3,474	6,540	75,348	0	3,000
26a	Wabash silt load (colluvial phase)	2,343	2,640	56,019	0	5,000
48	Wabash silty clay loam..	3,597	5,700	76,658	0	2,000
71	Genesee silt loam.....	3,030	4,680	52,416	0	6,000
89	Sarpy silt loam.....	3,840	3,000	26,496	1,350	0
91	Sarpy loam	2,586	2,340	28,076	1,080	0
102	Sarpy fine sandy loam..	2,304	720	6,891	480	0

TABLE VII. GREENHOUSE EXPERIMENT, GRUNDY SILT LOAM, MAHASKA COUNTY

Pot No.	Treatment	Green Weight Clover in Grams
1	Check	70.30
2	Manure	81.64
3	Manure+Lime	111.13
4	Manure+Lime+Rock phosphate	120.02
5	Manure+Lime+Acid phosphate	124.74
6	Manure+Lime+Complete commercial fertilizer	104.32

mercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in the experiment, the clover being seeded about one month after the wheat was up. Only the clover yields are given in the results on the Grundy silt loam and Tama silt loam from Mahaska county as the wheat yields were not secured. The yields of both crops are given in the other tests.

RESULTS ON GRUNDY SILT LOAM

The results secured in the experiment on the Grundy silt loam from Mahaska county are given in table VII, the yields being shown as green weights of clover only. Manure brought about a distinct increase in the clover and the application of lime with the manure had an additional effect which was very large. The acid phosphate and the rock phosphate both gave further increases, but the complete commercial fertilizer showed no effect. The beneficial effect of lime on clover grown on this soil is generally recognized among farmers and in-

Fig. 3—Tests on Grundy silt loam show the value of manure, lime and a phosphate fertilizer for wheat.

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

Pot No.	Treatment	Green Weight Clover in Grams
1	Check	83.91
2	Manure	149.68
3	Manure+Lime	195.04
4	Manure+Lime+Rock phosphate	201.85
5	Manure+Lime+Acid phosphate	249.48
6	Manure+Lime+Complete commercial fertilizer	242.67

creases secured in the field are frequently quite as large as those shown here. The effects of manure are likewise generally recognized and this material is considered one of the best fertilizers for use on this soil. The possibility of securing profitable crop increases from the use of phosphorus on this soil is quite clearly shown by these results. No definite conclusions can be drawn regarding the relative value of the two phosphorus fertilizers, but the desirability of testing them under farm conditions is quite evident. Manure, lime and phosphorus are certainly the fertilizing materials needed on the Grundy silt loam in order to bring about better crop growth.

RESULTS ON TAMA SILT LOAM

The results obtained on the Tama silt loam from Mahaska county are shown in table VIII. Again only the green weights of clover are given. Manure gave a very large increase in the yield of clover and this increase is in accord with that secured in most instances on the farm. The application of lime along with manure brought about a further distinct increase in the clover and this also is in accord with the results secured in practice. Lime always proves profitable

Fig. 4—Wheat and clover on Tama silt loam.

Fig. 5—Clover pot culture on Tama silt loam.

for growing legumes on this type. The application of rock phosphate had some effect on the clover, but the increase was not nearly so large as that brought about by the use of acid phosphate. The complete commercial fertilizer gave an increase only slightly less than that of the acid phosphate. It seems evident that phosphorus fertilizers may be of considerable value on this type, and while definite conclusions should not be drawn from individual tests, these results would indicate that acid phosphate might prove profitable on this soil, and probably more profitable than rock phosphate. Apparently the Tama silt loam will respond to applications of manure, lime and phosphorus. Which phosphate fertilizer should be used should be determined by tests on the individual farms.

RESULTS ON CLINTON SILT LOAM

The results secured on the Clinton silt loam from Wapello county are shown in table IX. The addition of manure to this soil gave a slight increase in the yield of wheat but a very considerable gain in clover. When lime was applied with the manure, the yields of both crops were increased considerably, the effect being the greatest in the case of the clover. Rock phosphate increased the yield of wheat quite definitely and showed a very large effect on the clover. Acid phosphate and the complete commercial fertilizer gave increases in both crops which were almost identical, showing less influence on both the wheat and the clover, however, than that evidenced by the rock phosphate. It is evident from these results that manure is a particularly valuable fertilizer on the Clin-

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

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	21.0	31.7
2	Manure	22.0	47.6
3	Manure+Lime	26.5	54.3
4	Manure+Lime+Rock phosphate	30.7	67.9
5	Manure+Lime+Acid Phosphate	30.5	58.8
6	Manure+Lime+Complete commercial fertilizer	30.7	58.9

TABLE X. GREENHOUSE EXPERIMENT, GRUNDY SILT LOAM, WAPELLO COUNTY

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

ton silt loam. Lime should be applied in addition to manure if satisfactory legume growth is to be secured, and increases will follow its use. Phosphorus fertilizers will probably prove profitable on this type and tests on individual farms of the relative value of rock and acid phosphate should be carried out.

The results secured on the Grundy silt loam from Wapello county are given in table X. Manure brought about the same effect on the clover in this experiment but showed little influence on the wheat. Lime in addition to the manure gave increases in both crops, the effect being quite definite in the case of the clover. Rock phosphate showed a considerable increase in wheat and a very large gain in the clover. Acid phosphate had little effect on the wheat but increased the clover yields to a larger extent than did the rock phosphate. The complete commercial fertilizer increased the wheat yields but to a smaller extent than did the rock phosphate. The increase on clover was smaller than that

Fig. 6—Manure increased the wheat yield on the Clinton silt loam. Acid phosphate with manure increased the yield more noticeably than did the rock.

Fig. 7—Clover pot culture on Clinton silt loam. Manure is of decided benefit. Rock and acid phosphate also proved of value, applied with manure.

brought about by either of the phosphorus carriers. These results very largely confirm those secured on the same type in Mahaska county and show the beneficial effect of manure, lime and phosphorus on this soil. Definite conclusions as to the comparative value of the two phosphorus carriers should not be drawn from these results, but they emphasize the need of testing these materials on individual farms and with various crops.

The results of the experiment on the Tama silt loam from Black Hawk county are given in table XI. The application of manure in this case had a slight effect on the wheat but increased the clover yield enormously. Lime applied with manure increased the wheat yields very slightly but gave a very large effect on the clover. Rock phosphate showed a distinct increase on the wheat and on the clover. Acid phosphate had less effect than the rock on the wheat but increased the clover to a much larger extent. The complete commercial fertilizer showed more effect on the wheat than did the acid phosphate but less than the rock phosphate, while in the case of the clover it had more effect than the rock phosphate but less than the acid phosphate. It is apparent from the results that manure is a particularly valuable fertilizer for use on this soil and that lime applied with manure is of large value in increasing clover yields. It exerts some effect also on the grain crops. Phosphorus fertilizers may be of considerable value on this soil and tests in the field should be carried out to determine whether rock phosphate or acid phosphate should be employed.

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

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	12.00	8.0
2	Manure	12.65	31.0
3	Manure+Lime	12.86	51 5
4	Manure+Lime+Rock phosphate	14.03	57.0
5	Manure+Lime+Acid phosphate	12.72	64.5
6	Manure+Lime+Complete commercial fertilizer	13.67	59.5

These greenhouse experiments as a whole indicate that the Grundy silt loam, the Tama silt loam and the Clinton silt loam, the main types in Mahaska county, will respond to applications of manure, lime and phosphorus. Manure is the fertilizer of largest value that can be used. Lime proves distinctly profitable, especially because of its large effect on legume growth. Phosphorus fertilizers will undoubtedly be profitable on these soils in the field. Just which material should be used, whether rock phosphate or acid phosphate, must be determined by actual tests on the farm.

FIELD EXPERIMENTS

A field experiment has been laid out in Mahaska county but thus far results have not been secured and hence no data are available from field work in this county. The experiment must be carried on for a period of years before the results can be considered satisfactory for interpretation. There are several field experiments under way in other counties, however, which are located on some of the leading soil types in Mahaska county and the results secured on these fields are undoubtedly indicative of the results which will be obtained in Mahaska county. The effects of applications of various fertilizing materals are quite clearly shown in the results, and it seems quite reasonable to conclude that the same materials would bring about very similar results in Mahaska county on the same soil types.

The data included in this report have been secured on the Clinton silt loam in Scott county, the Grundy silt loam in Henry and Wapello counties and the Tama silt loam in Black Hawk county. These fields are all located on land which is thoroly representative of the individual soil types. Corner stakes are installed to show the location of the plots and care is used in applying fertilizers and in harvesting the crops and securing the yields so that the results obtained may be considered highly dependable.

Each series of plots includes tests under the livestock system of farming and under the grain system. Manure is applied in the former system while crop residues serve as a source of organic matter in the latter. Fertilizer treatments tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. The manure is applied at the rate of 8 tons per acre once in a four year rotation. Limestone is added in a sufficient amount to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is applied at the rate of 2,000 pounds per acre annually and a standard 2-8-2 complete commercial fertilizer at the rate of 300 pounds per acre annually. In 1921 the standard brand employed was changed to conform to the new fertilizer standards and a 2-12-2 fertilizer is now being used on these plots at the rate of 267 pounds per acre annually. On the grain system plots, the second crop of clover is turned under, the corn stalks are cut with a disk and plowed under, and the threshed straw from the small grain is returned to the soil. These materials provide the crop residues. The series of plots consists of 13, 3 of which are untreated or check plots and are numbered 1, 7 and 13. Plots 1 to 7 are included in the livestock system while plots 7 to 13 are in the grain system.

The experiment at Mt. Pleasant on the Grundy silt loam in Henry county was laid out in 1915 and the experiments in Scott, Wapello and Black Hawk counties were laid out in 1917. These plots are all 155′ 7″ by 28′, or one-tenth of an acre in size. On the Princeton, Mt. Pleasant and Agency fields, the complete data for the full series of plots is included. In the case of the Farson field and the Hudson field, however, only the results for the livestock system plots are given, inasmuch as the results on the crop residue plots are evidently abnormal. They have not yet received sufficient treatment to show any effects.

In addition to these individual results from the fields mentioned, tables are given showing average yields of various crops grown on all the experiment fields in the state on the Grundy silt loam and on the Tama silt loam. With the former type, the corn yields are the average of eleven yields on nine fields. The oats are the averages of six yields on four fields. Clover yields are averaged from ten crops on eight fields and the wheat from four crops on four fields. With the Tama silt loam the figures are the averages of three yields on two fields in the case of corn and of two crops on two fields in the case of the oats. These two latter tables show rather definitely the results which may be expected on these two types of soil from the treatments practiced, and as a whole they confirm the conclusions which may be reached from a consideration of the results on the individual fields.

THE PRINCETON FIELD

The results obtained on the Princeton field located on the Clinton silt loam in Scott county are given in table XII. The results shown in this table indicate the effect of fertilization on winter wheat, corn, oats and clover on this type. Some interesting effects of treatment are shown in the case of all the crops grown. Manure produced a considerable increase in the wheat, corn and oats and a large increase in the case of the clover. The application of lime with manure gave further increases in the case of all crops. Rock phosphate with lime and manure showed beneficial effects on the wheat, corn and clover, but had practically no effect on the oats. Acid phosphate with the lime and manure showed increases on the wheat, corn, oats and clover, the effect being smaller than that of the rock phosphate on wheat and corn but greater in the case of the oats and the clover. The differences are not large and definite conclusions as to the relative effects of these two materials should not be drawn. The complete commercial fertilizer showed beneficial effects on the corn, oats and clover giving slightly larger returns than either the acid phosphate or the rock phosphate. No effect was evident on the wheat.

In the grain system the crop yields on the crop residue plots are not given for the years 1918 and 1919 as the yields were evidently not normal and there had been no additions. In the remaining years the results are shown and are practically duplicates of the check plots. Additions of lime had some effect on all the crops grown, the increase secured being very large in the case of the clover. Rock phosphate increased crop yields in every instance. Acid phosphate showed a larger effect than the rock in the case of one corn crop and in

the case of the oats but had less effect on the wheat and clover, showing gains in every instance except one. The complete commercial fertilizer showed slightly larger increases in crop yields than either of the phosphates, but the differences were not large enough to be distinctive.

It is apparent from this experiment as a whole that manure is a particularly valuable fertilizer to use on the Clinton silt loam. Lime will bring about beneficial effects when the soil is acid and these effects may be quite pronounced in the case of corn and small grain crops as well as in the case of clover. There are indications of value from the use of phosphorus fertilizers applied with manure and lime. Complete commercial fertilizers seem to have insufficient effect to warrant their use in preference to phosphates. Just which phosphate should be employed must be determined for the individual farm conditions. The results are very similar in the case of the grain system, there being indications of value from liming and the use of phosphates.

THE MT. PLEASANT FIELD

The results secured on the Mt. Pleasant field are given in table XIII. The yields for the first two years of the experiment are not included because of very evident abnormality. The yields for the two duplicate series of plots for this field are given together in the table. The yields on the check plots in the case of the corn and oats are the averages of three checks, 1, 7 and 13. In the case of the clover crop the checks are averaged for the livestock system and the grain system separately. In the former, the total yields from both crops of clover on

TABLE XII. FIELD EXPERIMENT PRINCETON FIELD
Clinton Silt Loam—Scott County

Plot No.	Treatment	Winter Wheat bu. per A. 1918	Corn bu. per A. 1919	Corn bu. per A. 1920	Oats bu. per A 1921	Clover tons per A. 1922
1	Check*	33.5	61.8	59.6	25.8	1.50
2	Manure	37.4	67.6	68.3	28.4	1.93
3	Manure+Lime	43.0	68.2	70.6	32.1	2.13
4	Manure+Lime+ Rock phosphate..	47.4	67.8	73.5	31.9	2.25
5	Manure+Lime+ Acid phosphate ..	45.2	64.0	70.8	35.1	2.29
6	Manure+Lime+ Complete commercial fertilizer.....	37.3	63.4	73.0	36.4	2.34
8	Crop residues	....**	....**	58.6	29.6	1.47
9	Crop residues+Lime	31.7	62.4	67.3	29.7	2.14
10	Crop residues+ Lime+Rock phosphate	35.0	64.1	68.7	29.8	2.28
11	Crop residues+ Lime+Acid phosphate	31.7	66.6	61.5	31.1	2.18
12	Crop residues+ Lime+Complete commercial fertilizer	36.2	65.2	69.5	30.8	....***

*The check plot yields in 1 are the averages of the yields on plots 1, 7 and 13.
**Yields not given because of very evident abnormality.
***Yield not secured.

the three checks are averaged while in the grain system the check yield is the average of the first crop of clover on plots 7 and 13.

There are some variations in the results secured on this field and in certain years on individual plots the results appear to be somewhat abnormal. Thus in one or two instances, the effects of manure are not evident over the check plots but in general it may be said that the application of manure to this soil is very desirable and brings about a profitable increase in crop yields. This is certainly true when the results are averaged over the period of a rotation. On both the 100 and 200 series, the effects of manure may be considered as showing definite value. When lime was applied along with manure large increases were secured in crop yields in practically all instances. The effects are particularly noticeable in the case of the clover but large gains are shown also with the corn and oats. Apparently lime is of value on this type because of effects on all the crops of the regular four year rotation.

Rock phosphate showed large increases in the yields of the various crops, the influence being particularly evident in the case of the oats and clover. Acid phosphate also increased the yields of the various crops, in many instances showing larger effects than the rock phosphate. In a few cases, however, the reverse is true. The results would hardly permit of definite conclusions as to which material would be the most desirable, but they seem to indicate that over the six year period on this field, acid phosphate is somewhat preferable. The complete commercial fertilizer showed effects which were about the same on the average as those obtained with the acid phosphate. Apparently this material has no very pronounced superior effects over the acid phosphate.

In the grain system plots there has been some treatment with crop residues after the first few years of the experiment and there is evidence of increased yields due to the thoro utilization of the crop residues. Again lime brings about an increase in the yields of the crops grown altho in several instances the

TABLE XIII. FIELD EXPERIMENT, MT. PLEASANT FIELD
Grundy Silt Loam—Henry County

Plot No.	Treatment	1917		1918		1919		1920		1921		1922	
		100 Corn	200 Oats	100 Oats	200 Clover	100 Clover	200 Corn	100 Corn	200 Corn	100 Corn	200 Oats	100 Oats	200 Clover
1	Check	48.1	93.1	73.7	7883	8300	57.3	48.3	76.2	58.0	33.9	44.7	3.0
2	Manure	37.5	85.0	75.1	9650	7580	66.3	57.0	74.9	56.7	46.9	39.8	3.1
3	Manure+Lime	55.2	90.0	74.8	10600	7990	74.1	76.6	82.2	59.5	35.3	62.1	3.3
4	Manure+Lime+Rock phosphate	66.0	107.5	76.5	11450	9860	78.6	81.8	88.6	67.5	42.6	63.3	3.5
5	Manure+Lime+Acid phosphate	73.6	97.5	85.1	12575	12950	75.3	77.7	101.4	72.8	48.9	70.1	3.8
6	Manure+Lime+Complete commercial fertilizer	76.8	97.5	80.8	10850	13870	66.5	67.5	88.4	64.9	46.5	70.6	3.9
7	Check*	48.1	93.1	73.7	4575	4380	57.3	48.3	76.2	58.0	33.9	44.7	1.9
8	Crop residues	50.8	91.3	81.3	5650	4600	65.3	67.5	80.7	65.7	43.1	54.5	2.3
9	Crop residues+Lime	47.1	92.5	93.2	4250	4450	71.0	80.6	84.5	66.1	40.0	49.0	2.6
10	Crop residues+Lime+Rock phosphate	52.7	100.0	96.4	5985	5700	75.1	90.0	83.3	65.0	43.8	57.9	2.5
11	Crop residues+Lime+Acid phosphate	54.7	92.5	99.9	6545	6420	81.1	75.5	99.9	66.9	43.5	54.8	2.5
12	Crop residues+Lime+Complete commercial fertilizer	52.8	107.5	93.6	5390	6300	78.5	51.2	107.9	67.1	42.2	61.9	2.6

*The check yields given under 7 are the same as under 1 in the case of the corn and oats, the figures being the average of the three check plots. In the case of the clover in 1918 and 1919, however, the yields in 7 are the averages of the first clover crop on plots 7 and 13, the second crop being turned under on the crop residue plots. In 1922 only one crop of clover was secured. The clover yields in 1 are the averages of both clover crops on all three check plots.

effects were not pronounced. In general the results are not nearly as definite as on the livestock system plots. Farm experience proves very definitely the desirability of liming this soil when it is acid. Rock phosphate and acid phosphate both gave considerable increases in yields of corn, oats, and clover, in all but one case. In several instances the acid phosphate seems to be somewhat superior to the rock and would average up somewhat better for the six year period. In general conclusions are rather difficult to draw and it should be emphasized that these two materials should be tested by individual farmers before a choice is made. The complete commercial fertilizer had effects which in general were very little greater than those produced by the phosphates, and hence it would seem that the phosphates would prove more economically desirable. It seems evident that on the Grundy silt loam manure is a valuable fertilizer, lime should be applied and there is rather distinct evidence that a phosphorus fertilizer would prove profitable.

THE AGENCY FIELD

The results secured on the Agency field on the Grundy silt loam in Wapello county are given in table XIV. In these results the yields on the check plots are the averages of the results secured on plots 1, 7 and 13. The beneficial effect of manure on this soil is quite definitely shown on the corn, oats, wheat, clover and timothy, the increase being very definite in all cases. Lime in addition to manure gave still further increases on the corn, wheat and clover but showed no effect on the oats. Rock phosphate proved of large value on all the crops grown, and acid phosphate likewise showed definite increases. In most cases the acid phosphate seemed to have a somewhat greater effect than the rock. Increases were secured with the use of the complete commercial fertilizer, but they were not quite as large in most instances as those secured when acid

TABLE XIV—FIELD EXPERIMENT. AGENCY FIELD
Grundy Silt Loam—Wapello County.

Plot No.	Treatment	Corn bu. per A. 1918	Oats bu. per A. 1919	Winter wheat bu. per A. 1920	Clover & timothy tons per A. 1921	Timothy tons per A. 1922
1	Check*	58.4	50.4	22.7	1.76	2.20
2	Manure	64.5	62.2	31.5	2.09	2.20
3	Manure+Lime	66.7	58.3	36.7	2.20	2.25
4	Manure+Lime+Rock phosphate	68.7	63.6	38.7	2.52	2.30
5	Manure+Lime+Acid phosphate	70.0	66.6	40.0	2.39	2.80
6	Manure+Lime+Complete commercial fertilizer	66.0	65.6	34.7	2.52	2.50
8	Crop residues	58.5	49.0	31.4	1.81	2.20
9	Crop Residues+Lime.	61.2	59.5	**	2.02	2.40
10	Crop Residues+Lime+Rock phosphate	61.7	61.2	36.4	2.33	2.65
11	Crop Residues+Lime+Acid phosphate	63.5	61.2	36.3	2.19	2.75
12	Crop Residues+Lime+Complete commercial fertilizer	62.5	52.0	35.6	2.17	2.65

*The check plots yields are the averages of the yields on Plots 1, 7 and 13. **Yield not secured.

phosphate was applied. It seems that this material would be less desirable on this soil than a phosphorus fertilizer.

The crop residues had a slight effect during the last few years but in the first years of the experiment there was so little material applied that no effect could be expected. The addition of lime proved very desirable in all cases on the residue plots. Rock phosphate and acid phosphate both brought about distinct effects on the various crops grown, there being very little choice between the two materials. The complete commercial fertilizer seemed slightly less effective than the phosphorus carriers. The results secured on this field in Wapello county very largely confirm those secured on the Mt. Pleasant field in Henry county and show that on the Grundy silt loam, manure is a valuable fertilizing material, lime should be applied when needed and phosphorus fertilizers will probably prove of value. Just which material should be employed must be determined for individual farm conditions.

THE FARSON FIELD

The results obtained on the Farson field on the Grundy silt loam in Wapello county are given in table XV. The yields secured on the grain system plots are not included inasmuch as there has been little effect of treatment. It is evident from these results under the livestock system of farming, that manure is a valuable fertilizing material for use on this soil. Lime in addition to manure brought about increases which were particularly noticeable in the case of clover. Rock phosphate and acid phosphate both give distinct crop increases, the acid phosphate apparently being somewhat superior to the rock. The differences are not definite enough, however, to warrant the drawing of conclusions. The complete commercial fertilizer gave crop increases which in some cases were slightly larger than those produced by the phosphates. This was not true with all the crops, however, and in general the effects seemed to be very little different than those produced by the phosphates on the average. Apparently the use of a phosphate fertilizer on this soil would be more desirable than the application of a complete commercial fertilizer. Again these results confirm those secured on the same soil type in Henry county and on another field in Wapello county. They show

TABLE XV. FIELD EXPERIMENT. FARSON FIELD II.
Grundy Silt Loam—Wapello County

Plot No.	Treatment	Oats bu. per A. 1918	Wheat bu. per A. 1919	Clover ton per A. 1920	Corn bu. per A. 1921	Oats bu. per A. 1922
1	Check	72.2	11.7	1.23	69.8	27.2
2	Manure	72.2	11.7	1.19	80.4	....*
3	Manure+Lime	70.0	15.2	1.43	78.6	44.1
4	Manure+Lime+Rock phosphate	72.2	16.1	1.42	79.1	49.8
5	Manure+Lime+Acid phosphate	70.0	14.8	1.83	79.0	55.5
6	Manure+Lime+Complete commercial fertilizer	74.3	14.6	1.66	81.8	46.0

*Yield not secured.

TABLE XVI. FIELD EXPERIMENT. HUDSON FIELD
Tama Silt Loam—Black Hawk County

Plot No.	Treatment	Corn bu. per A. 1918	Oats bu. per A. 1919	Corn bu. per A. 1920	Corn 1921	Oats bu. per A. 1922
1	Check	45.8	47.6	53.2	.....	44.8
2	Manure	49.3	54.7	62.8	no	53.1
3	Manure+Lime	54.4	59.2	67.4	crop	59.6
4	Manure+Lime+Rock phosphate	56.5	64.9	73.3	secured	58.1
5	Manure+Lime+Acid phosphate	57.4	62.2	73.3	.....	53.2
6	Manure+Lime+Complete commercial fertilizer	58.5	57.5	72.4	.....	62.2

the value of manure and lime, and indicate quite definitely that phosphorus fertilizers may prove distinctly profitable.

THE HUDSON FIELD

The results obtained on the Tama silt loam in Black Hawk county are given in table XVI. Again only the yields obtained under the livestock system are given as the crop residue plots are not yielding definite enough results. In 1921 the crop was not secured on these plots.

Manure brought about a distinct increase in the crop yields in all cases on this soil. Lime in addition to manure gave a further increase in the corn and oats. The application of rock phosphate and of acid phosphate showed still further increases in practically all cases. These two materials exerted very similar effects and a choice cannot be made as to which one should be employed on this soil until more complete data are secured. The complete commercial fertilizer gave distinct crop increases, but in most cases the effects were very little larger than those produced by the phosphates. In some instances the material seemed less effective. Apparently the phosphate fertilizers are more desirable for use on this soil than the complete brands. The results as a whole indicate clearly that manure is a very valuable fertilizer for application to the Tama silt loam. Lime should be applied when the soil is acid as is usually the case, and a phosphorus fertilizer would undoubtedly yield profitable returns. Whether rock phosphate or acid phosphate should be employed must be determined by tests under individual farm conditions.

AVERAGE RESULTS OF FIELD EXPERIMENTS ON THE TAMA SILT LOAM

The average results of all the field experiments on the Tama silt loam are given in table XVII. The check or untreated plot averages are calculated from the yields on the three check plots in each field, 1, 7 and 13, and averages are then struck from the check yields on all the fields. These results show rather interesting effects of fertilizer treatment on the soil and while the number of fields represented is not large, rather definite conclusions may be drawn from the results. The application of manure increased the yield of corn and oats on this type to a very definite extent. Lime in addition to manure gave further increases which were larger than might be expected on these crops inasmuch as this material usually exerts its largest effect on the legume crop of the rotation.

The application of rock phosphate brought about a large additional effect on the two crops, the influence being particularly evident in the case of the corn altho the oats was increased to almost as large an extent. Acid phosphate proved of slightly more effect than the rock in the case of the oats, but had a smaller effect on the corn. The complete commercial fertilizer showed a distinct increase in both crops, the effect being more evident in the case of the oats. Crop residues increased the corn and oats to some extent, and the addition of lime brought about a still further increase which is particularly evident in the case of the oats. Rock phosphate and acid phosphate both gave considerable increases, the acid phosphate proving somewhat superior to the rock with both the corn and the oats. The complete commercial fertilizer showed less effect than the phosphates on the corn but a larger effect on the oats.

It is evident from these results that manure will yield profitable effects on the Tama silt loam and that lime should be used and will prove beneficial on the corn and small grain crops of the rotation as well as on the legume. Phosphorus fertilizers are of value on this type and just which phosphate fertilizer should be used must be determined under individual farm conditions. In some instances the rock phosphate seems somewhat preferable but in other cases acid phosphate is more profitable. The latter material generally shows better effects where manure is not available for use. The complete commercial fertilizer gives definite crop increases but these are not as profitable as those secured from the use of the phosphates because of the larger cost of the complete fertilizers.

AVERAGE RESULTS OF FIELD EXPERIMENTS ON THE GRUNDY SILT LOAM

The average results obtained from all the experiment fields on the Grundy silt loam are given in table XVIII. As in the preceding case, the check yields are the averages of the yields on the three check plots on each field averaged for all the fields represented. There is some definite evidence of the value of ap-

TABLE XVII. TAMA SILT LOAM

Average Crop Yields and Increases Due to Fertilizer Treatment
Iowa Experiment Fields

Treatment	Corn*		Oats*	
	Bu. per acre	Increase from treatment Bu. per acre	Bu. per acre	Increase from treatment bu. per acre
Check	63.3	.....	46.0	.....
Manure	69.6	6.3	49.4	3.4
Manure+Lime	71.8	8.5	56.3	10.3
Manue+Lime+Rock phosphate	77.7	14.4	58.6	12.6
Manue+Lime+Acid phosphate	75.3	12.0	56.7	10.7
Manure+Lime+Complete commercial fertilizer	73.7	10.4	62.9	16.9
Crop Residues	69.7	6.4	47.0	1.0
Crop Residues+Lime	71.8	8.5	57.9	11.9
Crop Residues+Lime+Rock phosphate	74.4	11.1	58.9	12.9
Crop Residues+Lime+Acid phosphate	75.7	12.4	63.3	17.3
Crop Residues+Lime+Complete commercial fertilizer	72.7	9.4	68.0	22.0

*The corn yields are the averages of 3 years results on 2 fields. The oats yields are the averages of 2 years results on 2 fields.

TABLE XVIII. GRUNDY SILT LOAM

Average Crop Yields and Increases due to Fertilizer Treatment.
Iowa Experiment Fields

Treatment	Corn*		Oats*		Clover*		Winter wheat	
	Bu. per acre	Increase from treatment Bu. per acre	Bu. per acre	Increase from treatment Bu. per acre	Tons per acre	Increase from treatment Tons per acre	Bu. per acre	Increase from treatment Bu. per acre
Check	56.9	.....	45.6	.....	1.98	.....	22.4	.....
Manure	62.9	6.0	49.6	4.0	2.14	0.16	29.2	6.8
Manure+Lime	67.3	10.4	56.6	10.0	2.34	0.36	32.5	10.1
Manure+Lime+Rock phosphate..	69.0	12.1	60.2	14.6	2.65	0.67	34.2	11.8
Manure+Lime+Acid phosphate...	72.7	15.8	64.9	19.3	2.86	0.88	34.7	12.3
Manure+Lime+Complete commercial fertilizer	69.2	12.3	61.7	16.1	2.83	0.85	33.1	10.7
Crop residues	60.3	3.4	51.6	6.0	2.23	0.25	25.1	2.5
Crop residues+Lime	61.9	5.0	53.3	7.7	2.33	0.35	.....	.....
Crop residues+Lime+Rock phosphate	63.0	6.1	61.5	15.9	2.62	0.64	28.8	6.4
Crop residues+Lime+Acid phosphate	64.8	7.9	59.3	13.7	2.65	0.67	28.9	6.5
Crop residues+Lime+Complete commercial fertilizer	65.8	8.9	56.9	11.3	2.62	0.64	28.3	5.9

*Corn yields averaged from 11 years results on 9 fields; oats from 6 years results on 4 fields; clover from 10 years results on 8 fields; and wheat from 3 years results on 3 fields.

plications of various fertilizers indicated in these results, and inasmuch as a rather large number of fields are represented and a good many crops, the results may be considered quite conclusive. The application of manure to the Grundy silt loam proved distinctly profitable, increases being secured with all the crops. Lime in addition to manure was always desirable on this soil and gave profitable increases on all crops in the rotation. Its effect was not limited to the legume, but was evidenced on the corn and small grain crops of the rotation. Rock phosphate applied with manure and limestone gave increases in all cases and acid phosphate likewise proved of value on all the crops. The effects of acid phosphate on this type were considerably greater than the effect of the rock phosphate. The complete commercial fertilizer showed more effect than the rock phosphate, but did not prove as valuable as the acid phosphate when applied with manure and lime. The use of crop residues gave some effect on the crops grown and lime in addition proved of value just as was noted in the results obtained when it was used with manure. The rock phosphate increased crop yields but the acid phosphate gave larger effects in most instances. The complete commercial fertilizer gave increases which were very similar to those obtained with the acid phosphate.

These results as a whole show a very definite value from the application of manure to the Grundy silt loam. Lime is very necessary for the best legume growth and will prove of value on the other crops of the rotation. Phosphorus fertilizers show effects both with manure and with crop residues, the increase being the greater where the manure is applied. Acid phosphate seems to be somewhat more effective than the rock, but the results are very similar with the

two materials and hence farmers should test the two phosphates and determine for their own conditions which one should be used. The complete commercial fertilizer showed increases which were very similar to those produced by the phosphates therefore this material cannot be considered as desirable as the phosphates. It is interesting to note that the average results on the Grundy silt loam as given in the above table and also the results on the Tama silt loam in table XVII bear out very definitely the indications shown in the individual field experiments discussed earlier. Apparently on these two soil types at least there is very definite evidence of the value of manure, lime and phosphorus.

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

The general treatments recommended for the soils of this county are based upon the laboratory, greenhouse and field experiments discussed in the previous pages. While the field experiments are under way in other counties, the soil types on which they are located are representatives of some of the main types in Mahaska county and the results may be considered quite definitely indicative of the effects which may be secured in this county from the use of the same fertilizing materials. The recommendations are also based upon the general experience of farmers and the suggestions made have been proven valuable by considerable practical experience. The data from the field experiment in this county will be available after several years results have been secured, but there is sufficient evidence at present from the individual fields referred to and from the average field experimental results discussed, to show rather definitely the principal needs of the soils of Mahaska county.

Farmers should appreciate the fact that the suggestions made may all be put into effect on the farm and that the tests suggested are simple and may be easily carried out. Many farmers are conducting fertility tests on their own farms and are securing results of large value to themselves and of considerable interest to others located on the same soils. The Soils Section of the Iowa Agricultural Experiment Station is ready to aid farmers who wish to carry out tests on their soils. It will be much more satisfactory in the long run for the farmers to test out the value of such materials as phosphorus fertilizers by making applications to small areas, and then if profitable returns are secured, applications may be made to extensive areas with the assurance of profit.

LIMING

The soils of Mahaska county have all been shown to be acid in reaction and hence the need of lime on the soils of this county is quite evident, and in general there seems to be indicated in the tables a rather large demand for lime. The upland soils are apparently quite strongly acid. In a few instances there is a small lime content in the lower soil layers, and the samples do not react acid, but in no case is there any considerable amount of lime present, hence these soils

will all need to be limed in the very near future or they will become distinctly acid. Soils which are under cultivation and are intensively cropped tend to lose their lime content rather rapidly because of utilization by crops, losses by leaching and also because of the production in the soil of acids with which the lime reacts. As acidity increases in the soil with the disappearance of lime, the fertility becomes lower and it becomes increasingly difficult to secure satisfactory crop growth, particularly in the case of legumes. Red clover and alfalfa are very sensitive to acidity and if satisfactory production of these crops is to be secured, lime must be used on an acid soil.

The application of lime to soils is valuable from the fertility standpoint because it improves the physical conditions, the chemical conditions, and the bacteriological conditions in the soil. It opens up heavy clay soils making them better aerated and it tightens up light sandy soils, making them more retentive of moisture and plant food and less subject to injury by drought. Lime improves the soil chemically because it neutralizes the acids which are produced from the decomposition of organic matter in the soil. If these acids are allowed to accumulate they often bring about injurious effects. It also supplies the necessary plant food calcium and with many crops this may be of large value. It improves soils bacteriologically because desirable soil bacteria will not act properly unless the soil is well limed. Decomposition processes will not proceed properly, nitrate production will not occur, nitrogen fixation will be restricted and in general the production of available plant food will be limited so that crops may suffer. In some cases the application of lime may increase crop yields because of improved physical conditions of the soil, because of the chemical effect or because of better conditions for bacterial growth. In general, however, it seems probable that the beneficial effect of lime is due to the influence on all these conditions together.

The amount of lime which should be applied to soils will vary with the individual soil conditions. Figures given earlier in this report indicate the needs merely of the samples tested and should not be taken to show the general needs of the soil types. Soils vary widely in lime requirement, even within types and hence tests should always be made on every field before lime is used. In this way it is possible to supply sufficient lime and to avoid too small an application, both of which are undesirable economically. Farmers may test their own soils for lime needs but it will probably be more satisfactory if they will send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge.

The farmers of Mahaska county should see to it that their soils are tested and that lime is applied as needed if they are to secure the best crop growth. Furthermore, it should not be concluded that one application of lime will be sufficient for all time. Tests should be made at regular intervals at least once in a four year rotation to insure the maintenance of a proper amount of lime in the soil. The tests should be made preferably preceding the growing of the legume crop of the rotation and the lime may then be applied where it is most needed, that is for the legume. Other soil treatments are less valuable and frequently show no effects whatever on an acid soil, hence the use of lime should be con-

sidered as a fundamental soil treatment. Further information regarding the loss of lime from soil, the need of lime by certain crops and other points in connection with liming, are given in Bulletin 151 and Extension Circular 105 of the Iowa Agricultural Experiment Station.

MANURING

The soils of Mahaska county are quite generally low in organic matter and while not strikingly deficient, there is evidence of a need for fertilizing materials to build up and maintain the organic matter supply. The application of manure is particularly desirable on all the soils of the county as is evidenced by the beneficial effects secured from the use of this material indicated in the greenhouse and field experiments discussed earlier in this report. The practical experience of many farmers confirms the results indicated above in showing the large fertilizing value of manure on the various soils of the county. No other fertilizer proves as profitable as does manure and in fact other fertilizing materials quite generally give smaller effects when applied to soils in the absence of manure. Wherever manure is produced on the farm and is available for utilization, it should be considered a fundamental fertilizer treatment for the soils. Manure exerts a beneficial effect on the soils of Mahaska county even where there is apparently a sufficient supply of organic matter present, and in fact the results are often more striking in such cases than on soils which are lighter in color and apparently poorer in organic matter.

Manure is of value on soils because of its influence on the physical, chemical and bacteriological conditions in the soil. Heavy, impervious soils are opened up, made less retentive of moisture and better aerated. Light open soils are made more retentive of moisture, less open and porous and less apt to lose valuable plant food constituents by leaching. Manure supplies actual plant food to the soil and hence it has a chemical effect. It contains a large portion of the plant food contained in the feed of the animals, and serves, therefore, to return to the soil much of the fertility removed by the crops grown and used as feed. It serves to prolong the life of the soil by increasing the period of time which must elapse before any one of the essential elements will become deficient. Manure supplies a large amount of organic matter to soils and this has a chemical effect on the soil and also a physical and bacterial effect.

Enormous numbers of bacteria are contained in manure and these organisms are responsible for the production of available plant food. The organic matter supplied with the bacteria furnishes them with food material, hence there is a stimulation in all forms of desirable bacterial action, and soil conditions for the best crop growth are much improved. In many cases the application of manure may prove of value largely because of the stimulation of bacterial action and better production of available plant food. On soils apparently well supplied with organic matter and not strikingly low in plant food constituents, the bacterial effects of manure are undoubtedly of most importance. In general crop increases secured from the use of manure may be attributed to a combination of bacterial, chemical and physical effects.

Manure is a waste product on the farm and too often it is improperly stored and handled so that it undergoes large losses before being applied to the soil. The value of these losses is quite commonly overlooked. Experiments have shown that when stored in uncovered heaps exposed to the weather and the liquid portion allowed to wash away, manure may lose as much as 90 per cent of the valuable constituents present. When such losses are permitted actual money loss occurs because of the fact that the effect of the manure on crop growth is correspondingly reduced. Crop increases are much less from the application of improperly stored manure, and the difference in effect from well handled manure brings a difference in actual income on the farm. If carefully stored and applied, manure may return to the soil 75 to 80 percent of the plant food removed in the crops grown. It is very necessary that precautions be taken on the farm to prevent losses from manure. It may be stored in a covered yard or pit or in some other manner. No one method of storing can be recommended for all conditions but in general it may be said that any method which will keep the manure moist and compact and protected from the weather will prove satisfactory. Farmers may be assured that any small expense involved in properly storing manure will be well warranted by the increased crop returns secured from its use.

Usually 8 to 10 tons of manure is applied per acre once in a four year rotation. In general no larger application than this is possible on the average farm because of insufficient production of manure. In some cases larger amounts of manure might be used with profit but if large applications are made to one field some other portion of the farm will usually be left without treatment. The average application mentioned may be considered about the maximum on any farm where care is taken to apply manure to all the soils. There is little danger of putting on too much manure, but it may be mentioned that it is rarely advisable to apply more than 16 to 20 tons for ordinary farm crops. In garden or truck farming, larger applications may often be made with profit.

In grain farming no manure is available for application to the soil and hence some other material must be employed to keep up the organic matter supply. On the livestock farm the amount of manure produced is often insufficient to meet the soil needs and some material must be used to supplement the manure. In both cases green manuring may be practiced to advantage. Legumes are most profitable for use as green manures because they have the ability when well inoculated to draw upon the nitrogen content of the atmosphere and thus they act as a nitrogenous fertilizer as well as a source of organic matter, having a double value on the soil. Non-legumes may be employed in some instances where the nitrogen factor is not so important but in general if organic matter is needed, nitrogen is also low and legumes should be employed. Many legumes are available for use as green manures. Some one may be chosen which will fit in with almost any farming and cropping system and under the particular soil and climatic conditions. In many cases in Mahaska county, green manuring would undoubtedly prove of value from the standpoint of increasing crop yields and making the soils more productive. The practice should not be followed carelessly, however, nor blindly, as it may prove quite undesirable if conditions are

not satisfactory. Thus, if the soil is too dry the green material may not decompose rapidly enough and there may be some injury to the moisture condition in the soil. Suggestions regarding green manuring, under special conditions will be given by the Soils Section upon request. Frequently the second crop of clover is turned under in the soil and this serves as a partial green manuring crop. The clover seed may be removed and the remainder of the crop turned under with good effect on the soil. In some instances a legume may be seeded in the corn at the last cultivation and turned under to improve the fertility condition of the soil.

Organic matter may be applied to the soil by a proper utilization of all crop residues such as straw and stover. Frequently these materials are burned or otherwise destroyed and their value is lost. They contain considerable amounts of fertility constituents as well as organic matter, and hence they have a double value on the soil. They may be utilized for feed or bedding and returned to the soil mixed with the manure, as is the common practice on the livestock farm. On the grain farm they may be stored and allowed to decompose partially before application, but under both systems of farming the proper utilization of the crop residues is very important from the standpoint of keeping up the organic matter supply. When crop residues are properly used, farm manure is applied without having suffered losses of valuable constituents, and leguminous crops are utilized as green manures, the organic matter content of soils may be kept up and large yields of crops insured.

THE USE OF COMMERCIAL FERTILIZERS

Many of the soils in Mahaska county are rather poorly supplied with phosphorus, and it would seem that phosphorus fertilizers would probably be of value in many cases at the present time. They will certainly be needed on these soils in the near future if satisfactory crop yields are to be secured. The greenhouse experiments and field tests referred to earlier in this report give rather definite indications of value from the use of phosphorus fertilizers on some of the more extensive types in the county. It would seem, therefore, that many farmers in the county would find it profitable to test the application of a phosphorus fertilizer to a small area. They could then determine the desirability of applying the same material to a large area.

The total phosphorus content of soils indicates merely the store of phosphorus, and does not necessarily show how much of the element will be provided in an available form for plant use. A low content of phosphorus indicates quite definitely that there will not be a sufficient production of available phosphorus.

When the total supply in the soil decreases, the amount made available decreases much more rapidly, hence a low content of total phosphorus shows rather definitely a need for phosphorus fertilization. Even where the total supply is not low, however, available phosphorus fertilizers may prove profitable if the element is not being changed into a soluble form sufficiently rapidly to keep crops supplied. Even on those soils in Mahaska county where the supply of phosphorus is not extremely low, therefore, applications of a phosphorus fertilizer might be very desirable.

Two phosphorus fertilizers, rock phosphate and acid phosphate, are available for use agriculturally. Rock phosphate is slowly available in soils and rather large applications must be made to secure beneficial effects. Acid phosphate contains the element in an available form and it is more expensive, but smaller applications may be used with desirable effects. The field tests which are now under way in the county, include the use of both these materials. The experiments in other counties described in this report likewise include both fertilizers. Evidence is not yet sufficient, however, for a choice to be made between them for use on the soils of Mahaska county. Comparative results from the two materials must be secured for several years and with different crops before definite conclusions can be drawn. It would seem that for the present farmers should test both of these materials on their own soils and thus they may readily determine for their own conditions which fertilizer will give the most profitable returns. Accurate comparisons of value will depend upon the actual crop increases secured and a calculation of the value of these increases over against the cost of the treatments. It is comparatively a simple matter to test the use of these phosphorus fertilizers on the farm and if definite results are secured on small areas then the farmer may apply the particular material which gives the best results to a large area with the assurance of profit. Directions for carrying out such field tests on the farm are given in Circular 82 of the Iowa Agricultural Experiment Station and the farmers of Mahaska county are urged to aid in the general solution of the phosphorus problem by determining the needs of their own soil by the aid of these simple field tests.

The soils of the county are not strikingly deficient in nitrogen but the amount present is insufficient to provide for continued production of satisfactory crops over any number of years. Under cultivated conditions where crops are removed and the soil is well drained, nitrogen is constantly taken out of soils, and the supply gradually decreases. It is quite essential that some means be employed to maintain the supply of this element in the soil. In several of the types the addition of nitrogenous fertilizers might prove profitable at the present time, particularly if natural materials such as farm manures or leguminous green manures are employed. These two materials are the most commonly utilized nitrogenous fertilizers, and they are most desirable for general farming purposes.

On the livestock farm the careful storage and return of manure to the land will go far toward keeping up the nitrogen supply. On the grain farm leguminous green manure crops must be utilized in place of manure. Where the supply of manure is insufficient, green manuring should be practiced also. Every rotation should contain a legume, and if the legume is well inoculated and all or part of the crop turned under in the soil, considerable nitrogen may be added. If the legume is removed from the land there will be no increase in nitrogen, and if it is not inoculated the crop will not act in any way as a nitrogenous fertilizer. It is important, therefore, to insure thoro inoculation of the legume and to plan on at least a partial return of the green material of the crop if the nitrogen supply of the soil is to be increased. Frequently only the seed of the legume is removed and the remainder of the crop is plowed under. This is a very desirable method of handling the legume crop. Occasionally legumes may

be used as catch crops, and in this way the entire crop is utilized for increasing the nitrogen and organic matter content of the soil.

Crop residues when turned under in the soil constitute a means of returning to the land a portion of the nitrogen removed, and it is very important that they be properly utilized if the nitrogen supply is to be maintained. These materials along with farm manures and green manures are the natural fertilizers available for maintaining the nitrogen supply in the soil, and they may also be utilized to increase the supply of this element and the organic matter content.

Commercial nitrogenous fertilizers may be utilized in small amounts as top-dressings to stimulate the early growth of crops, but their use for general farm crops on the soils of this county cannot be recommended at the present time. If tests on small areas prove them to be of value they may be utilized, but generally leguminous green manures are much cheaper and quite as satisfactory for keeping up the nitrogen in soils.

Analyses of many of the soils of the state made earlier showed a large content of potassium in practically all of them. It seems hardly likely, therefore, that potassium fertilizers would prove profitable on general farm crops. Only where the production of available potassium is insufficient would it be desirable to add a small amount of a commercial potassium fertilizer. Small applications of the muriate or sulphate of potassium might be quite desirable as top-dressings to stimulate the early growth of some crops but these materials should not be applied generally until the value has been shown by tests. If the soil is kept in the best physical condition, well supplied with organic matter, and properly drained and aerated, there should be a sufficient production of potassium in an available form to supply crop needs for many years. Some of the field tests now under way in the state include a potassium fertilizer and hence results are being secured which may later indicate whether or not these materials may be profitably employed. For the present it can merely be recommended that farmers who are interested test the application of a potassium carrier to a small area before they make any extensive applications.

Complete commercial fertilizers are not recommended at the present time for general use in this county for the reason that experimental evidence at hand on the field tests indicate that the phosphorus fertilizers are more profitable. The complete brands are more expensive than the phosphorus carriers and must bring about much larger crop increases if they are to prove profitable. The results given earlier in this report show very little value from the complete brands over the acid phosphate and hence it would seem that the nitrogen and potassium carried in the complete fertilizer has little effect on the soil. Even if nitrogen in nitrate of soda and potassium in muriate of potash give some effects as top-dressings, the complete brands would not necessarily prove as desirable as the use of the individual fertilizers owing to the fact that the nitrogen is not necessarily in the same form. Results are being secured continually with complete fertilizers and the data are proving quite definite.

Farmers may test the use of any complete brand of fertilizer on their own soils and if profitable returns are secured they may apply the material to a larger area with the assurance of profit. Such materials should be tested in com-

parison with a phosphorus carrier, however, if definite conclusions are to be drawn as to the relative value of the complete fertilizers. There is no objection to the use of complete commercial fertilizers and in fact in many cases where truck farming is practiced, such materials can be applied very profitably. For general farming on the main soil types of Mahaska county it seems that phosphorus fertilizers are of more value.

DRAINAGE

The soils of Mahaska county as a whole are quite adequately drained. The map given early in this report indicates the extent of the natural drainage system and shows that artificial drainage is needed only in a few instances. There are a few areas, small in extent, in the Grundy silt loam on the level uplands where tiling would be of value. The Grundy silty clay loam is quite generally in need of artificial drainage. The Putnam silt loam on the upland sometimes is in need of tiling. On the terraces the Bremer silty clay loam and the Calhoun silt loam are frequently too wet and occasionally the Bremer silt loam will be improved by tiling. Several of the Wabash soils on the bottoms need drainage but these types also need protection from overflow if the soils are to be made properly productive.

Wherever soils are too wet, tiling is very necessary and in fact should be the first treatment to make the soils properly productive. It should be emphasized that the installation of tile is a paying proposition when judged from the standpoint of the value of the increase in crops secured and the farmers in Mahaska county may be certain that tiling out wet land will prove profitable to them.

THE ROTATION OF CROPS

The proper rotation of crops is necessary on all soils if satisfactory yields are to be secured from year to year. The continuous growing of any one crop reduces the fertility of the soil very rapidly due to undesirable conditions which result in the soil. Even if the crop grown is a money crop, and of more value than the other crops in the rotation, the total income from the land over a period of years will prove greater where a rotation is practiced. The yields of crops are so reduced under continuous cropping that frequently their growth becomes unprofitable and the farmers are forced to adopt a rotation. Conditions should not be allowed to reach such an extreme state, however, and too much emphasis cannot be placed on the importance of following a proper rotation on every farm.

No one rotation can be recommended for use under all conditions. Several satisfactory rotations are in use thruout the state and a few of these which are suitable to conditions in Mahaska county are suggested in this report. It should be noted that these rotations may be modified as desired to fit in with local conditions. In fact almost any rotation will prove desirable provided a legume is included and the money crop. The following rotations are suggested for use in this county.

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.)

THE PREVENTION OF EROSION

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

Slowly falling rain may be very largely absorbed by the soil, provided 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 apt to be subject to erosion while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are 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 the 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 to

gether 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 gulling. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of the 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 it 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.

Erosion occurs to an injurious extent in several of the soils in Mahaska county. The Clinton silt loam is badly washed in many areas, particularly in the more rolling locations. The Lindley silt loam of the upland is also very frequently injured considerably by the washing action of water. In fact, in many cases most of the surface soil of the Lindley has been washed away. There has been some injurious erosion in the case of the Jackson silt loam on the terraces, but the effect of washing is not extensive on the second bottom soils. It is important to consider briefly the causes of erosion and the methods which may be employed to prevent or control washing inasmuch as these methods should frequently be utilized to prevent serious injury to the Clinton silt loam, the most extensive upland type.

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

EROSION DUE TO DEAD FURROWS

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

"Plowing in."—It is 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 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 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 upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, 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 in 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 it 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 satisfaction is the staking in operation recommended for the control of the 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 brush-piles may be installed up the course of the gully and with the regular repair of washouts or undercuttings may prove very effective.

The modification of this system of "staking in" which is being used with success in some sections, consists in covering the bottom and side 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 upstream. 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 loosely, 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, 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 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 gul-

lies. 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 lowlying 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 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 bottom land, 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 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 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.

DESCRIPTION OF INDIVIDUAL SOIL TYPES IN COUNTY*

DRIFT SOILS

There is one drift soil in the county which is classified as the Lindley silt loam. It is of minor importance, covering 4.0 percent of the total area.

LINDLEY SILT LOAM (32)

The Lindley silt loam occurs in all parts of the county in narrow areas occupying generally the slopes to the stream courses. It occurs in association with the Clinton silt loam and the Union silt loam, frequently separating the Clinton silt loam from the bottomlands. The larger areas occur along Black Oak, Muchakinock and St. Joseph creeks and tributaries of the North and South Skunk rivers.

The Lindley silt loam is a light yellowish-brown or brown silt loam grading at 8 to 10 inches into a yellowish-brown gritty silty clay loam. At 18 to 20 inches it passes into a brown, stiff clay mottled with drab. The subsoil contains a large percentage of sand, gravel and small stones. In some areas the type approaches a loam in texture, especially where it occurs on the steeper hillsides and eroded slopes. Frequently the soil in these locations is darker in color than the typical. The surface soil is probably of loessial origin, the underlying drift of Kansan origin approaching close to the surface because of the washing away of the loessial covering. The drainage of the type is quite adequate. It is subject to erosion and unless properly handled and protected from washing, may be very seriously washed.

Only a few areas of the type have been cleared and brought under cultivation. The native forest growth includes white oak, hickory, ash, hazel, and elm. Where cultivated, corn and oats are grown, but the yields are not very satisfactory, be-

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

ing usually lower than on the other upland types. Because of its very rough topography and tendency to erode, most of the type should probably be kept in bluegrass and used for pasture. Comparatively little of it is used for cultivated crops. It is very low in organic matter and if cultivated should receive liberal applications of farm manure or green manure crops. It is acid and in need of lime and it would undoubtedly respond to applications of phosphorus fertilizers. It should be protected from erosion whenever cultivated and some of the methods suggested in an early section of this report may be utilized to prevent the formation of gullies and the even more serious sheet washing. The value of the type is greatest from the pasture standpoint.

LOESS SOILS

There are six loess types in the county, classified in the Clinton, Tama, Grundy, Knox, and Putnam series. Together they cover over three-fourths of the county, 76.9 percent.

CLINTON SILT LOAM (80)

The Clinton silt loam is the largest individual soil type in the county as well as the largest loess soil. It covers 33.4 percent of the total area. It is widely distributed thruout the county, occurring in irregular belts along both sides of the North and South Skunk rivers and the Des Moines river. The most extensive areas occur in the southwestern part of the county in association with the Tama silt loam. The type occurs in general between the more level to gently rolling uplands of the Tama and Grundy series and the rough areas of the Lindley which adjoins the bottomlands. The individual areas are very largely cut by the streams and bottomlands. In many instances the Clinton silt loam separates the broad upland areas from the bottoms without the occurrence of any intervening types, while in other cases, there are small areas of terrace soils particularly along the Des Moines and Skunk rivers. Much of the type is rough and broken in topography, particularly near the streams on steep slopes, in ravines and on narrow ridges. A portion of the type might have been separated as a broken phase as was the case in Wapello county, but the distinction was rather difficult in this county and hence no phase was separated.

The Clinton silt loam consists of 8 to 12 inches of a light brown to buff colored smooth silt loam. When dry the surface soil is often a light gray and may resemble the Marion silt loam. In wooded areas the surface material is somewhat dark colored, due to accumulations of organic matter. The subsurface soil is a more compact brown silt loam to light silty clay loam. At lower depths the subsoil becomes a distinct silty clay loam to clay varying in color from yellow to brown, usually mottled with gray. The type is so closely associated with the Grundy Tama, and Putnam silt loams that in many instances it is very difficult to draw exact boundaries between the soils. Small areas of the Marion silt loam occur in this county but their total acreage is so small that they have been included with the Clinton silt loam. The Marion silt loam is a light, ashy gray soil with a heavy, compact, very impervious subsoil. Three areas occur in the county, one two miles northeast of Bellefontaine; a second, one mile southwest of Givin and a third about three miles south of Tioga in White Oak township.

In topography the Clinton silt loam is extremely variable, some having a rather rough to broken surface while other areas are almost level. The average topography is gently rolling to rolling except where the topography is level and here artificial drainage is usually needed. The heavy subsoil occurring in these flat areas is quite impervious and the difficulty in handling these areas of the type has led to their being called "hard-pan". Drainage is the chief treatment needed by these areas to make them readily cultivable.

The type was originally forested with oak, hickory, hazel, wild cherry and other trees. About 35 per cent of it is still in pasture and forest and much of this portion of the soil should probably not be cultivated. The areas which are at present under cultivation seem to be fairly productive when conditions are favorable. The area under cultivation is increasing as each year additional areas of the type are being cleared. In the cultivated areas the chief crops grown are corn, oats, wheat, clover, and timothy. Corn yields 20 to 75 bushels per acre, oats 20 to 60 bushels, wheat 10 to 35 bushels, and clover from 1 to 1½ tons of hay per acre. The type is well adapted also to the growing of apples, pears, cherries, small fruits and berries. It is readily cultivated except in the rough areas and in general is handled under the livestock farming system.

Crop yields are very much increased on this soil by proper methods of fertilization. It is low in organic matter and will respond to applications of farm manures. It is rather low in nitrogen and leguminous green manures will serve to supply this constituent. It is acid in reaction and should be limed if the best growth of legumes is to be secured. It is not well supplied with phosphorus, and phosphorus fertilizers will probably prove profitable on the soil in many cases at the present time. Experiments which have been carried out on this type indicate a profit from the use of phosphorus. Farmers are urged to test the value of rock phosphate and acid phosphate on this soil. The soil is apt to wash badly and may be seriously injured thru the formation of gullies. From among the suggestions made earlier in this report, some method may be chosen to prevent the growth of gullies and the washing away of the surface soil. The steeper slopes should undoubtedly be kept in sod as much as possible and many cultivated fields should be protected by the use of cover crops during the winter. Deeper plowing and the addition of organic matter would aid materially in cutting down the injurious effects of washing. The drainage of the type is usually adequate, frequently excessive. In a few instances tile drainage would be of value.

TAMA SILT LOAM (120)

The Tama silt loam is the second largest type in the county covering 22.4 per cent of the total area. It occurs in practically all parts of the county, occupying usually the gently rolling upland area which separates the level Grundy on the divides from the more strongly rolling to broken Clinton on the slopes to the streams. There are many rather extensive individual areas, but in general the type is found in comparatively narrow strips separating the Grundy from the Clinton as is characteristic in the northern part of the county or joining the Clinton as is characteristic of the areas in the southern part of the county.

Fig. 8—Gently rolling slopes of Tama silt loam sometimes erode.

The surface soil of the Tama silt loam is a dark brown to black friable silt loam 10 to 12 inches in depth. It is usually dark brown when dry and black when wet. It grades gradually into a lighter brown silty clay loam, friable and crumbly when not too wet. In topography it is undulating to rolling. It is entirely derived from loessial material and is free from stones and boulders. The type is well drained and rarely is there any need for artificial drainage.

Practically all of the Tama silt loam is under cultivation, general farm crops being grown. Corn yields about 50 bushels per acre, oats 50 to 75 bushels per acre. Good yields of clover and timothy are secured in favorable seasons. The yields of these crops and other general farm crops grown are very satisfactory.

This type is a relatively fertile one and crop yields are quite generally good. It will respond, however, to fertilizer treatments. It seems to be fairly well supplied with organic matter but applications of farm manure prove of large value and bring about very profitable crop increases. It is acid in reaction and applications of lime are very necessary if satisfactory legume growth is to be secured. The phosphorus content of the soil is not high and phosphorus fertilizers seem to prove of value in many cases. It is probable that acid phosphate or rock phosphate could be used with profit on many of the Tama areas. Just which material should be employed can only be determined by tests on individual farms. Farmers may test the value of these materials by applications to small areas and thus determine the desirability of their more extensive use.

GRUNDY SILT LOAM (64)

The Grundy silt loam is the third largest soil type in the county, covering 20.3 percent of the total area. It occurs most extensively in the southeastern part, altho there are considerable areas of the type in the northern, eastern, and central portions. Only small areas occur south of the Des Moines river. The major

portion of Cedar township and a large part of Harrison and Spring Creek townships are covered by this type. It is found on the broad, level divides between the streams and on the gentle slopes. It is usually separated from the rougher areas adjacent to the streams by areas of the more rolling Tama which in turn are separated from the streams by the strongly rolling areas of Clinton and Lindley.

The surface soil of the Grundy silt loam is a dark brown to black mellow silt loam 8 to 12 inches in depth. It grades gradually into a moderately friable brown to dark brown, light silty clay loam. At 18 inches it becomes a dark drab, yellowish-brown to dark brown, heavy, tenacious silty clay, mottled dark drab and yellowish brown. The yellow mottlings become more pronounced at the lower depths. Iron concretions occur in the lower subsoil. In some areas the subsurface layer is somewhat mottled and may be slightly gray in color, giving the type some of the characteristics of the Putnam soils. Occasionally the lower subsoil is so noticeably heavy and tenacious that it is locally called "hard pan." It is frequently quite difficult to draw an accurate boundary between Grundy silt loam and the Tama, as these types gradually change from one to the other. Topographic differences are usually evident, but in some instances do not serve as a distinct characteristic. Small areas of the Grundy silty clay loam too small to show on the map are included with the silt loam.

In topography the Grundy silt loam is level to gently rolling but drainage is ordinarily fairly well established. On a few of the more level areas, the installation of tile would be of material value in removing excess moisture. Most of the type is under cultivation or in pasture. It was never forested and native vegetation consisted of grasses. It is utilized for the growth of general farm

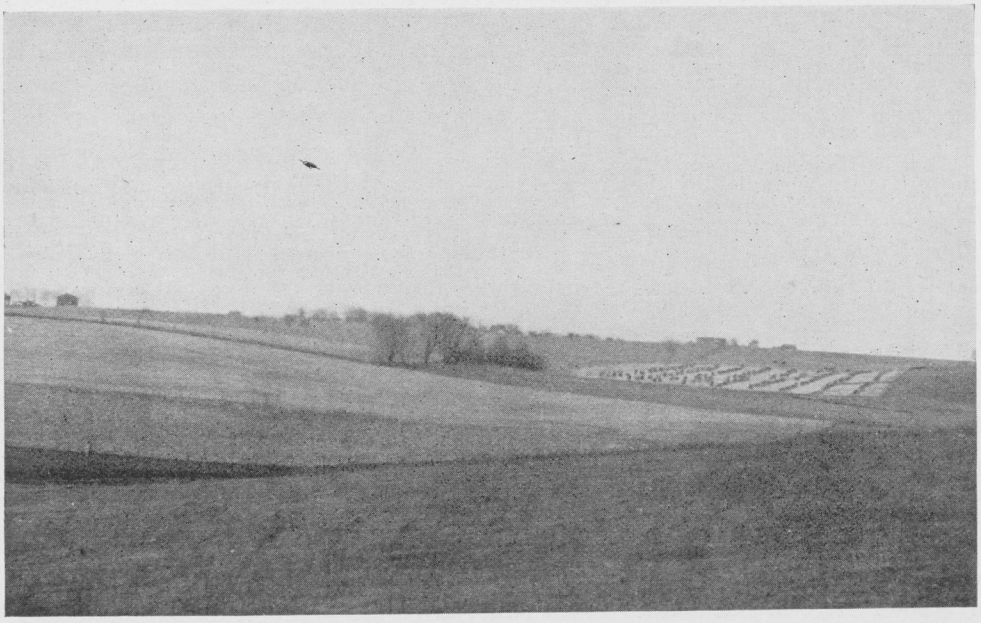


Fig. 9—Tama silt loam in Mahaska county.

Fig. 10—Rolling Tama silt loam in bluegrass pasture.

crops, corn being grown the most extensively. Other crops include oats, hay, wheat, rye, buckwheat and barley. Yields of corn range from 35 to 100 bushels per acre, averaging about 45 bushels. Oats yield 25 to 65 bushels per acre, wheat 12 to 40 bushels, and timothy and clover, from 1 to 3 tons of hay per acre.

Crop yields on this type are quite generally satisfactory but larger crops may be secured when the soil is properly handled. Practically all of it is suitable for cultivation and may be utilized for the growth of general farm crops. In a few instances drainage is very desirable and the installation of tile would prove of large value. Applications of farm manure yield large effects on this soil and prove distinctly profitable. The type is acid in reaction and should be limed for the best growth of legumes. It is very desirable that a good crop rotation be practiced which should include a legume. By the proper growing of legumes the nitrogen content and organic matter content of the soil may be maintained. These materials are often of large value in addition to the use of farm manure. Phosphorus fertilizers often give profitable crop increases and the tests given earlier in this report indicate considerable value from the application of rock phosphate or acid phosphate. Farmers are urged to test the relative value of these two materials on their own soils and thus determine which can be used the most profitably.

KNOX FINE SAND (33)

The Knox fine sand is a minor loess type in the county, covering 0.3 percent of the total area. It occurs in several small areas in the county, the largest of which is just north of Eddyville along the Des Moines river. This area is about one square mile in extent. Other small areas occur northeast of Eddyville and 4½ miles north of Oskaloosa. Still smaller areas are found south of Peoria and west and south of Indianapolis.

The surface soil of the Knox fine sand is a loose incoherent fine to medium sand, gray to grayish-brown in color, usually changing very little to a depth of 3 feet. In some places the subsoil ranges from a light brown to orange or yellow in color. The surface topography varies from undulating to dune-like and drainage is well established.

The type is relatively unimportant agriculturally, only about three-fourths being under cultivation. The remaining portion is occupied by a sparse growth of wild plum, scrub oak, shrubs, grass and sand burs. On the cultivated portions the most important crops grown are melons, small fruits and truck crops with some hay and corn. This type is best adapted for the growing of truck crops and to be made productive should receive liberal applications of farm manure and would be benefited by the turning under of leguminous green manures. It is low in plant food and should receive applications of fertilizing materials especially designed for truck crop growing on sandy soil. Complete fertilizer brands will prove profitable when used on this soil for truck crops. There are several brands on the market that may be used and it should be kept in mind that the soil is low in nitrogen, phosphorus and potassium and fertilization should include an application of these elements. The type is acid in reaction and should be limed, especially for the growth of legumes.

GRUNDY SILTY CLAY LOAM (115)

The Grundy silty clay loam is a minor type in the county, covering 0.3 percent of the total area. It occurs in several small areas in association with the Grundy silt loam on the uplands. It occurs chiefly in the southeastern part of the county the largest area being developed in the vicinity of Wright. Smaller areas are scattered over the upland south of Wright in Harrison and Cedar townships. There are a few small areas in other parts of the county.

The surface soil of the Grundy silty clay loam is a black, friable, silty clay loam 6 to 10 inches in depth, grading into a heavy compact plastic tenacious clay which breaks down into small cubes when dry. At 18 to 20 inches it passes into a bluish or yellowish-gray clay mottled with yellow and brown, the mottlings increasing with depth. Below 30 inches the clay subsoil is slightly less compact. In topography the type is flat to depressed and this, together with the compact subsoil renders drainage quite inadequate.

All of the soil is under cultivation, corn being the principal crop grown, followed by oats, wheat, grasses and clover. It is highly productive and the yields of all these crops are quite satisfactory. When well drained the yields are even higher than on the adjoining silt loam. The Grundy silty clay loam is chiefly in need of drainage to make it more productive and it should be handled with care in cultivation. It should not be plowed when too wet or too dry, as it is difficult to secure a uniform seed bed. Altho high in organic matter, the type will respond to small applications of farm manure but this material should not be applied preceding the small grain crop owing to the danger of lodging. The type is acid in reaction and should be limed, especially for the growth of legumes. Phosphorus fertilizers will also be needed in the future.

PUTNAM SILT LOAM (66)

The Putnam silt loam is a very minor type in the county, covering but 0.2 percent of the total area. It is found in five areas, four of them in West Des Moines township south of Lakonta. The largest area is just south of this town with two small areas to the east. The two remaining areas are on the Monroe county line, one in Jefferson township and one extending over the boundary between Jefferson and West Des Moines township.

The surface soil of the Putnam silt loam is a dark gray silt loam 8 to 10 inches in depth. The soil appears almost black in color when wet. The subsurface soil consists of a distinct layer of ashy gray to white silt 6 to 8 inches in thickness. Below this the subsoil is a heavy silty clay loam to clay, mottled gray, brown and yellow. In flat, poorly drained areas, the soil is a light gray in color, while in other areas which are better drained it is dark brown to black. In topography the type is level and drainage is poor.

This soil is all under cultivation, and the same crops are grown as on the adjacent Clinton and Tama uplands. Crop yields are very much the same as those secured on the Clinton soils. The type is in need of drainage primarily if it is to be made satisfactorily productive and it will respond profitably to applications of farm manure or the use of leguminous green manures. It is acid in reaction and should be limed, and phosphorus fertilizers will undoubtedly prove of value.

TERRACE SOILS

There are eight terrace types in the county, classified in the Bremer, Waukesha, Jackson, Calhoun, Buckner, Judson and Plainfield series. These types

Fig. 11—Highway thru level area of Grundy silt loam.

are all minor in area and together they cover only 5.0 percent of the total area of the county.

BREMER SILT LOAM (88)

The Bremer silt loam is the most extensive terrace type, covering 2.0 percent of the area of the county. It occurs on low terraces along many of the streams in the county, being most extensively developed along the Des Moines river There are other considerable areas, however, along the North Skunk river and along the South Skunk river. The largest individual area is found along the Des Moines river southwest of Fosterdale. Other areas somewhat smaller are found south of Bolton, two miles north and east of Leighton along the South Skunk river and northwest of Indianapolis along the North Skunk river. There are many smaller areas along the rivers of the county and also in the vicinity of many of the smaller creeks.

The surface soil of the Bremer silt loam is a very dark brown, smooth, uniform silt loam to a depth of 10 to 12 inches. The surface soil is black heavy silty clay loam grading into a heavy tenacious clay dark brown to black in color, and mottled with drab and yellow in the lower parts of the three-foot section. A few variations from the typical soil have been included owing to their small extent. In the area south of Fosterdale small areas of the Bremer loam are included in the type as they were too small to separate on the map. The topography of the type is level to slightly undulating and owing to its position and heavy subsoil condition, drainage is generally poor.

Nearly all of the Bremer silt loam is under cultivation, corn, oats, and hay being the principal crops grown. Yields of all these crops are quite generally satisfactory when the type is drained, and it is considered a highly productive soil. The first treatment needed in many instances is the installation of tile to insure adequate drainage. The soil will respond to application of farm manure, and it should receive additions of lime as it is always acid in reaction. The phosphorus content is not high and applications of phosphorus fertilizers would undoubtedly be of value.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the second largest terrace type in the county, covering 1.4 percent of the total area. It occurs in numerous areas in the county being most extensively developed along the Des Moines river and along the North Skunk river. The largest areas are found northeast of Lakonta in the vicinity of Bolton and three miles northwest of Indianapolis. Numerous other small areas are found along the rivers and creeks of the county.

The surface soil of the Waukesha silt loam is a dark brown to black friable silt loam 10 to 12 inches in depth. At this point it changes to a light brown silt loam grading gradually to a somewhat lighter, heavy silty clay loam at the lower depths. There are small patches of Waukesha loam, a dark brown to black loam included with the silt loam because of their small area. These patches of the loam are found in the areas of silt loam mapped a mile and a half and two miles and a half southeast of Bolton and south of Fosterdale. In these areas the sur

face soil is distinctly loamy while the subsoil contains more or less coarse material, the amount increasing at the lower depths. A few small areas have been included with the type where the subsoil is much lighter textured than typical. In topography the Waukesha silt loam is level to slightly undulating. Drainage is usually very satisfactory.

Practically all of the type is under cultivation and all the general farm crops are grown. Corn yields about 45 to 50 bushels per acre and in general yields of all crops are about the same as on the better upland soils. This type may be made more productive by better methods of soil treatment. Applications of farm manure are very desirable and bring about large effects on crop yields. Leguminous green manure crops may also be used profitably in some cases. The type is acid in reaction and should be limed for the best growth of legumes. It is not high in phosphorus and applications of phosphorus fertilizers would be of value in many cases.

JACKSON SILT LOAM (81)

The Jackson silt loam is a minor type in the county, covering 0.8 percent of the total area. It is found in several small areas in the county on the terraces of the Des Moines, North Skunk and South Skunk rivers and Muchakinock and Middle creeks. Areas are also found along some of the smaller streams of the county. All of the areas of this type are small in extent.

The surface soil of the Jackson silt loam is a light brown to dark brown silt loam 10 to 12 inches in depth. The upper subsoil is a light brown heavy silt loam streaked with gray. The lower subsoil is a brown heavy silty clay loam mottled with yellow and gray. Within the type there are included a few small areas of soil varying somewhat in color and texture. In some places along the uplands sandy materials have been washed over the type, forming narrow strips of a darker colored soil. These variations from the typical soil are included with the type because of their small extent. In topography the soil is level to slightly undulating and drainage is usually quite adequate.

The greater part of the type is under cultivation, general farm crops being grown. Corn yields from 40 to 45 bushels per acre while oats, wheat, timothy and clover give satisfactory yields. Fruits, small fruits and garden crops are also grown on this type to some extent, chiefly for home consumption.

The Jackson silt loam is a rather productive type but crop yields may be increased considerably thru applications of various fertilizing materials. The use of farm manure is very desirable and liberal applications should be made. Leguminous green manure crops may often be used with very beneficial effects. The type is acid and in need of lime. It is low in phosphorus and applications of phosphorus fertilizers will undoubtedly prove profitable.

CALHOUN SILT LOAM (42)

The Calhoun silt loam is a minor type in the county, covering but 0.2 percent of the total area. It is found in small areas along the streams of the county, most of the areas being along the North Skunk river and Muchakinock creek. There are other areas, however, on the terraces along some of the other streams.

The surface soil of the Calhoun silt loam is a smooth, velvety, gray to gray-

ish-brown silt loam, 7 to 10 inches in depth. Below this it grades into a light silty layer, white or gray in color, usually mottled with brown iron stains. This layer varies somewhat in thickness but generally extends to about 18 inches, at which point it passes into a tough, hard, impervious clay subsoil, grayish-brown to brown in color usually mottled with yellow and drab. In topography the soil is level and due to this fact and to the heavy impervious subsoil, the drainage of the type is poor.

The soil is practically all under cultivation, general farm crops being grown. Corn, oats, wheat and hay are produced most extensively. Yields secured on the Calhoun silt loam are very much the same as on the upland Clinton silt loam and crops may be increased considerably by applications of fertilizing materials. Liberal amounts of farm manure should be applied and leguminous green manures should be used. The type is acid and in need of lime. Phosphorus fertilizers would undoubtedly prove of value. The first treatment the soil should receive before any fertilization is practiced, however, is the installation of an adequate drainage system.

BREMER SILTY CLAY LOAM (43)

The Bremer silty clay loam is a very minor type in the county, covering 0.2 percent of the total area. It occurs in small scattered areas along some of the streams of the county, being found chiefly along the North Skunk river and the Des Moines river.

The surface soil of the type is a black silty clay loam 6 to 8 inches in depth. Below this it grades into a dark brown or black heavy, compact, dense clay, somewhat lighter in color and mottled with dark drab and yellow. The topography of the soil is level and the drainage is poor.

About 50 percent of the type is under cultivation, corn being the principal crop grown, followed by oats, wheat and timothy. The soil is particularly in need of drainage to be made more productive. Altho the yields secured at the present time are fairly satisfactory, applications of various fertilizing materials will bring about larger effects. Small amounts of manure prove profitable. Applications of lime are needed and phosphorus fertilizers will undoubtedly prove of value.

BUCKNER LOAM (38)

The Buckner loam is a minor type in the county, covering 0.2 percent of the total area. It occurs in small areas chiefly along the Des Moines river, the largest area being found south of Fosterdale. Other smaller areas occur along the Des Moines river and some of the tributary streams.

The surface soil of the Buckner loam is 10 to 15 inches in depth and consists of a brown, loose structured loam. The subsoil is a dark brown loam becoming heavier in texture at the lower depths, grading into a silt loam or clay loam at 3 feet. In some places the soil varies little in color or texture thruout the soil section. In topography the type is level to gently sloping and drainage is usually quite satisfactory. There seems to be some relation between the topographic condition and the texture of the soil. In the depressions there is less sand while the elevations seem to contain slightly more sand.

Most of the type is under cultivation and corn, oats, hay and melons are the principal crops grown. Some vegetables and small fruits are produced for local use. Corn yields 30 to 50 bushels per acre and oats 20 to 35 bushels. This type is fairly productive but may be increased in producing power by proper treatments. It is low in organic matter and should receive liberal applications of farm manure and leguminous green manures. It is acid in reaction and should be limed. Phosphorus fertilizers would undoubtedly prove of value. Where vegetables or truck crops are grown complete fertilizers made up to favor the particular crop may often be applied with profit.

JUDSON SILT LOAM (131)

The Judson silt loam is of very minor importance in the county, covering 0.1 percent of the total area. It occurs in small areas along the Des Moines river and its tributaries, the largest area being south of Bolton along the river.

The surface soil of the Judson silt loam is dark brown in color and extends to a depth of 10 to 12 inches. The subsoil differs very little from the surface except that it is somewhat lighter in color. In topography it is slightly undulating and drainage is fair.

Practically all of the type is under cultivation. Corn, oats, timothy and clover are the principal crops grown. Corn is the most important crop, yielding 30 to 75 bushels per acre. Oats yield 20 to 35 bushels and hay 1 to 1½ tons per acre. This type is quite productive but can be improved in many cases thru proper drainage. Applications of farm manure are of value, lime is needed as the soil is acid, and phosphorous fertilizers will undoubtedly prove of value.

PLAINFIELD LOAMY FINE SAND (118)

The Plainfield loamy fine sand is a very minor type in the county, covering only 0.1 percent of the total area. It is found in two areas, one occupied partly by the city of Eddyville on the Wapello county line and the other north and west of Eddyville along the Des Moines river.

The surface soil of the type is a dark brown loamy fine sand, underlain at 12 to 15 inches by a light brown sand. With increasing depth the soil becomes lighter in color and coarser in texture. In topography the type is level, drainage is adequate to excessive.

The type is of little agricultural importance. That part of it not occupied by the town of Eddyville is used for the growing of watermelons, cantaloupes, truck crops and berries. When so utilized the type should receive liberal applications of farm manure or leguminous green manures. Fertilizing materials would be of value on the type, and complete brands particularly prepared for special truck crops may often give desirable effects.

SWAMP AND BOTTOMLAND SOILS

There are six swamp and bottomland soils in the county and these together with the colluvial phase of the Wabash silt loam and the area of riverwash make a total of eight areas of swamp and bottomland. The soils are classified in the Wabash, Genesee and Sarpy series and together they cover 12.9 percent of the total area of the county.

WABASH SILT LOAM (26)

The Wabash silt loam is the most extensive bottomland soil in the county. With the colluvial phase, which is minor in area, it covers 9.2 percent of the total area of the county. It is developed most extensively along the North and South Skunk rivers and the largest individual areas occur along the South Skunk river in the northwestern quarter of the county. Smaller areas of the type are found along the Des Moines river, Buckley, Middle, Cedar, Muchakinock and St. Joseph creeks and along many of the smaller streams.

The surface soil of the type is a dark brown to black silt loam usually 10 to 14 inches in depth. The upper subsoil is dark brown to black and generally somewhat heavier in texture. The lower subsoil is a drab or yellowish-gray clay loam mottled with brown. Near stream beds, pockets or layers of sand are frequently encountered. Small areas of a light brown silt loam and a brown sandy or fine sandy loam are included within the type as they are too small to separate on the map. These variations from the typical soil are most frequently encountered near the streams. In those areas where the type is associated with the Wabash silty clay loam there is a gradual change from the one type to the other and the boundary lines must frequently be drawn arbitrarily. In topography the soil is level and the drainage is poorly developed.

The type is subject to overflow and hence only a portion of it is under cultivation. The tree growth which occurs mainly near the stream channels, consists of oak, maple, elm, hickory and ash. On the cultivated areas corn, wheat, oats and hay are produced. Corn yields 25 to 85 bushels, oats 20 to 40 bushels, the larger yields being obtained under favorable seasonal conditions. Blue grass does well and the major portion of the type is utilized for pasture for cattle, sheep and hogs.

The Wabash silt loam is a relatively productive type and when protected from overflow and well drained, crop yields are very satisfactory. These treatments are, however, fundamentally necessary on this soil. Small applications of farm manure prove of value on the cultivated areas, the soil is acid and in need of lime and phosphorus fertilizers would undoubtedly prove of value.

WABASH SILT LOAM (COLLUVIAL PHASE) (26a)

The colluvial phase of the Wabash silt loam is minor in area in the county, covering 2.2 percent of the total area. It occurs in narrow V-shaped valleys along many of the smaller streams of the county and it is also found in narrow areas along the outer boundaries of the valleys along some of the larger streams. It is made up mainly of material washed down from the adjacent uplands and deposited over the bottomland.

The surface soil of this phase is a dark brown to black silt loam 10 to 12 inches in depth. The subsoil is a black, heavy silt loam to light silty clay loam extending to a depth of 20 to 24 inches and resting upon a coal black silty clay loam to clay. Occasionally the subsurface soil is streaked with brown and gray. There are some variations in texture in the soil, but it is predominantly a silt loam. Drainage is fairly well developed except in a few instances.

Only a small portion of the type is under cultivation and it is not important agriculturally. On the cultivated areas corn and hay give excellent yields. The

type is largely used for pasture and is most desirable for that purpose. When cultivated the soil is in need sometimes of drainage and occasionally of protection from erosion. It will be made more productive by applications of farm manure, it is acid and needs lime, particularly for legume growth and it will undoubtedly respond to applications of phosphorus fertilizers.

WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is the second largest bottomland soil in the county, covering 1.9 percent of the total area of the county. It occurs in many areas along the North and South Skunk rivers and the Des Moines river. The largest areas are found along the South Skunk river. Many smaller areas are found associated with the Wabash silt loam along some of the smaller streams.

The surface soil of this type is a dark brown to black friable silty clay loam 6 to 10 inches in depth. There is a very little change in color or texture between 10 and 20 inches, at which point there is a slight mottling with drab and rusty brown. At lower depths the sub-soil is a dark drab plastic clay mottled with brown and gray. Included within this type there are small areas of Wabash clay, a crumbly to granular black silty clay loam to clay underlain by a heavy, dark drab, sticky, waxy clay. These areas are not separated on the map because of their small extent. The type is level to flat in topography. It is poorly drained and subject to overflow.

Only a small portion of the type is under cultivation. Corn, oats, wheat, and hay occupy the cultivated areas. Blue grass does well and serves for pasture. The soil is naturally productive and when well drained, protected from overflow and properly handled crop yields are quite satisfactory. It should not be plowed when too wet or too dry as in either case the physical condition of the soil is not satisfactory. When used for cultivated crops it should be manured and limed and it probably would also respond to phosphorus fertilizers.

GENESEE SILT LOAM (71)

The Genesee silt loam is a minor type in the county, covering 0.8 percent of the total area. It occurs mainly along the Des Moines river altho small areas are found also along the North and South Skunk rivers and some of the minor streams of the county. The larger individual areas occur one and one-third miles southeast of Bellefontaine, two and one-half miles south of Givin and along Bluff creek from Lakonta to the Des Moines river.

The surface soil of the Genesee silt loam is a grayish-brown to light brown silt loam. When wet the surface is brown in color. The surface soil extends to a depth of 6 to 12 inches changing at that point to a slightly lighter colored soil, sometimes a silt loam in texture but usually a light silty clay loam. Generally the texture becomes somewhat heavier at the lower depths. A few areas of Genesee silty clay loam are included with the Genesee silt loam because of their small extent. These areas of the heavier textured type are located on the west side of Muchakinock creek where it empties into the Des Moines river, one mile north of Bellefontaine and in areas southeast of Bellfontaine along the Des Moines river. The soil is flat in topography but is usually well drained. It is subject to frequent overflow.

The greater part of the soil is under cultivation and is utilized mainly for

corn, oats and hay. Corn yields 25 to 75 bushels per acre, oats 20 to 40 and hay one to two tons. When utilized for general farm crops the soil should be protected from overflow. When this is accomplished it will respond to liberal aplications of farm manure, the application of lime and treatment with a phosphorus fertilizer. Crop yields may be increased by these treatments and the soil made more productive.

SARPY SILT LOAM (89)

The Sarpy silt loam is a minor type in the county covering 0.6 percent of the total area. It occurs chiefly along the Des Moines river northwest and southeast of Bellefontaine, one and one-half miles west of Fosterdale and one and one-half miles west and northwest of Eddyville. A few small areas are mapped along the North and South Skunk rivers.

The surface soil of the Sarpy silt loam is a brown silt loam having a uniform smooth texture extending to a depth of 12 to 14 inches. The subsoil is generally a light brown loam, loamy sand or fine sand. Occasionally small patches of a heavy textured Sarpy soil are found and these have been included with the silt loam because of their small extent. In topography the type varies from level to slightly undulating, occasionally being marked by low sandy ridges or by depressions in which the soil is somewhat heavier in texture. Drainage is well established. The type is subject to overflow, however, and to be utilized satisfactorily for cultivated crops must be protected from overflow.

Corn is the chief crop grown altho oats, timothy, alfalfa and clover are produced to some extent. Melons and truck crops are grown in some instances. A portion of the type is used for pasture. When cultivated this soil would respond to applications of farm manure and lime. It should undoubtedly receive phosphorus fertilizers also.

SARPY LOAM (91)

The Sarpy loam is a minor type in the county, covering 0.2 percent of the total area. It occurs mainly in small areas along the Des Moines river, the largest area being found a mile and a half south of Bolton.

The surface soil of the Sarpy loam is brown in color and it extends to a depth of 8 to 12 inches. The subsoil is a brown loamy fine sand. The areas are quite variable in texture and patches of loamy fine sand, fine sand and silt loam too small to separate out are included with the type. The prevailing texture is a loam. In topography the soil is level to slightly undulating. Some ridges are present. Drainage is quite satisfactory.

The type is not important agriculturally but it produces excellent yields of the common crops. Melons and other truck crops are particularly suited to this soil. When protected from overflow, crop yields may be quite satisfactory. The type will respond to treatments with farm manure and lime and probably also phosphorus fertilizers.

SARPY FINE SANDY LOAM (102)

This is a minor type in the county, covering 0.1 percent of the total area. It occurs in small areas along the Des Moines river and the North and South Skunk rivers. The largest occurrence is near the Marion county line north of Bellefontaine.

The surface soil of this type is a light brown to brown fine sandy loam extending to a depth of 8 to 15 inches. The texture of the surface soil is quite variable, ranging from a fine sand to a silt loam. Owing to their small extent these variations in texture could not be separated on the map. The subsoil is a brown loamy fine sand to fine sandy loam. Within the type there are included small areas of sand "blows" which consist of fine sand. These were too small to show on the map. In topography the type is almost level and drainage is quite adequate.

Probably about 50 percent of the soil is under cultivation, general crops being grown successfully. Melons and other truck crops could probably be grown very satisfactorily on this type. Crop yields may be increased on this soil thru liberal applications of farm manure, the use of lime and the application of phosphorus fertilizers. For truck crops complete brands of fertilizers may be used with profit. To insure satisfactory crops the soil should be protected from overflow.

RIVERWASH (53)

There is a small area of riverwash in the county, amounting to 0.1 percent of the total area of the county. It occurs along the Des Moines river and is subject to frequent overflow. It consists mainly of heaps of loose fine sand, sand banks and low-lying sandbars. It is usually a grayish-brown to gray sand, varying widely in texture. Gravel occurs in some areas. The material is practically non-agricultural. Occasionally a sparse growth of brush, willow and grasses occurs on it.

RESIDUAL SOIL

There is one residual soil in the county mapped as the Union silt loam. It is minor in extent, covering 1.2 percent of the total area.

UNION SILT LOAM (157)

The Union silt loam occurs mainly in the southwestern portion of the county in association with the Clinton and Lindley silt loams. It is found in narrow bands along deep drainageways, ravines and steep slopes. Most of the areas are found along North Coal, South Coal, Turkey Run, Little Bluff and Bluff creeks.

The surface soil of the Union silt loam is brown in color extending to a depth of 6 to 8 inches. The subsoil is a brown to gray or drab silty clay loam to clay splotched with yellow, brown and various shades of red. It contains fragments of limestone, shale and some sandstone. In many places the bed rock is reached within the three-foot section. The type is quite variable and in some places the surface soil is a silty clay loam while in others it is quite sandy. The boundary line between this soil and the Clinton and Lindley silt loams is frequently established rather arbitrarily as there is a gradual change from the one type to the others.

The soil is not important agriculturally and practically none of it is under cultivation. In topography it is rough and much of it has been very extensively eroded. It is largely forested with oak, hickory, hazel and other trees and shrubs.

APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

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

THE "SOIL DERIVED" ELEMENTS

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

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the

soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

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

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

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

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

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

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

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

REMOVAL OF PLANT FOOD BY CROPS

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

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

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

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

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

trogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

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

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

REMOVAL FROM IOWA SOILS

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

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

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported, revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the

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

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

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

CULTIVATION AND DRAINAGE

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

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

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

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

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

THE ROTATION OF CROPS

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

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

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotation. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes

in rotations is of particular value since when they are well inoculated and turned under, they not only supply organic matter to the soil, but they also increase the nitrogen content.

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

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

MANURING

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

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

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

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

THE USE OF PHOSPHORUS

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

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

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

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the

soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exceptions to the general rule, as was shown by the tests of many representative soils reported in Bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas are 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 divisions in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 12.

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

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

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a

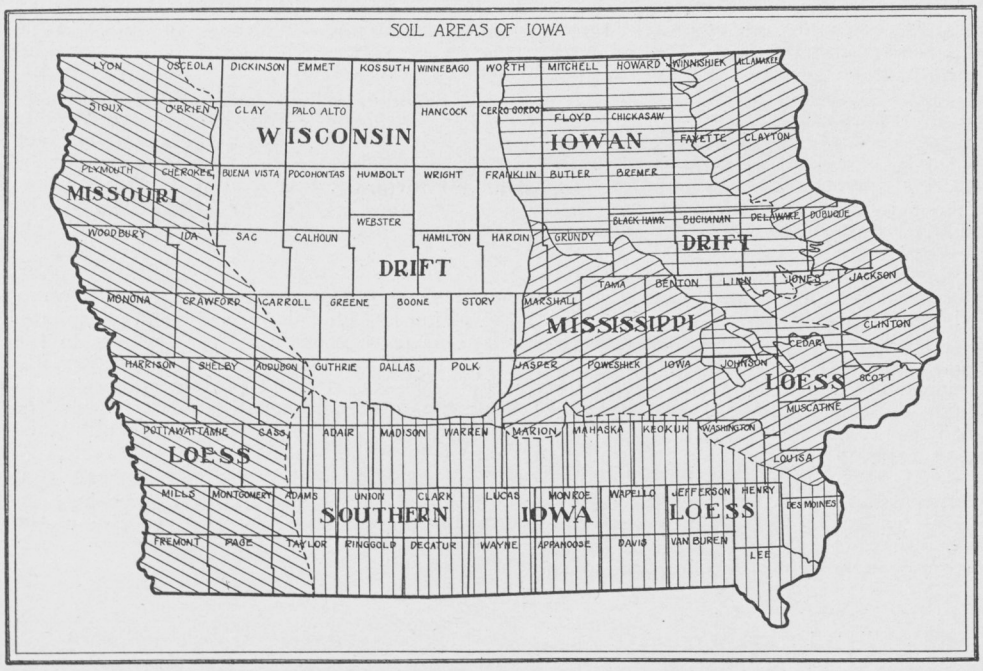


Fig. 12. Map showing the principal soil areas in Iowa

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

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

THE SOIL SURVEY BY COUNTIES

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

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

GENERAL SOIL CHARACTERISTICS

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

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

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

The common soil constituents may be given as follows:†

Organic matter	All partially destroyed or 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.

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

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 per cent clay, usually mixed with much silt; always more than 50 percent silt and clay.

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

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

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

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

Sandy Clays—20 per cent 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 per cent.

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 per cent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

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

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

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

Gravels—More than 50 percent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

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

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

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

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

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

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

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

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