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SOIL SURVEY OF IOWA

MILLS COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils



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Soil Survey Report No. 33
March, 1924
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March, 1924

Soil Survey Report No. 33

SOIL SURVEY OF IOWA

Report No. 33--MILLS COUNTY SOILS

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



Fig. 1. Duroc Jersey hog farm near Folsom. Lamoure silty clay loam.

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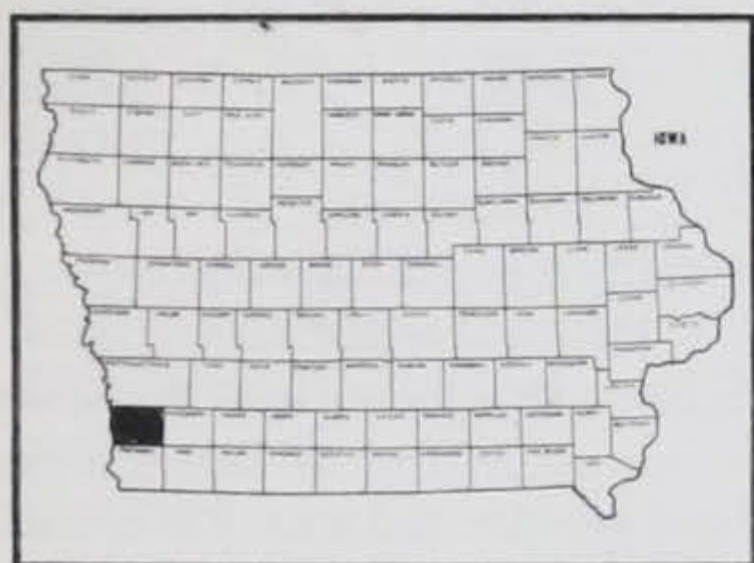
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MILLS COUNTY SOILS*

By W. H. Stevenson and P. E. Brown with the assistance of L. W. Forman and N. J. Russell.

MILLS COUNTY is located in southwestern Iowa, in the second tier of counties north of the Missouri state line and separated from the state of Nebraska by the Missouri river. It lies entirely within the Missouri loess soil area and the upland soils of the county are all of loessial origin. The bottomland



soils are likewise loessial, being made up of material carried from the uplands by the streams, reworked and laid down on the terraces and bottoms.

The total area of Mills county is 430 square miles, or 275,200 acres. Of this area, 256,365 acres or 93.1 percent, is in farm land. The total number of farms is 1,647 and the average size of the farms is 156 acres.

The figures given below show the utilization of the farm land of the county as given in the Iowa Yearbook of Agriculture for 1921.

Acreage in general farm crops.....	169,256
Acreage in farm buildings, feed lots and public highways.....	11,224
Acreage in pasture	67,522
Acreage in crops not otherwise listed.....	695
Acreage in waste land.....	6,017

The type of agriculture most generally practiced in Mills county is general farming, including cereal production with some dairying and some raising of hogs and other livestock. The tendency to specialization in dairying and livestock industries is increasing and a much larger proportion of the crops produced is constantly being utilized for feeding purposes.

Hog raising is the principal livestock industry, while the feeding of beef cattle is of slightly less significance. Dairying is becoming a more important industry in the county and many farmers are now selling their surplus milk to the creameries. A few dairies are located near towns. The development of the dairy industry in the county may confidently be expected in the future.

Trucking is practiced to some extent but it is not extensive. Orcharding is likewise of minor importance. Poultry raising is practiced on all farms, but rarely on a commercial scale.

The chief crops grown and sold out of the county include corn and oats and some alfalfa. The income of the county is thus derived from the sale of these crops, the sale of hogs and beef cattle and of dairy products, with a minor part coming from the sale of sheep, poultry products, truck crops and minor general farm crops.

There is a considerable area of waste land in the county, tho in many cases this land might be reclaimed and made productive if the proper methods of

*Soil survey of Mills county, Iowa, by G. B. Jones of the U. S. Department of Agriculture and N. J. Russell of the Iowa Agricultural Experiment Station.

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

Crop	Acres	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	106,000	41.34	40.0	4,240,000	\$ 0.30	\$1,272,000
Oats	20,000	7.80	26.0	520,000	0.23	119,600
Spring wheat	820	0.32	10.0	8,200	0.87	7,134
Winter wheat	16,000	6.24	18.0	288,000	0.90	257,200
Barley	470	0.18	30.0	14,100	0.42	5,922
Rye	210	0.08	18.0	3,780	0.73	2,759
Potatoes	656	0.25	50.0	32,800	1.40	45,920
Tame hay	10,500	4.09	1.7	17,800	9.08	161,624
Wild hay	3,300	1.28	1.5	4,950	7.47	36,976
Alfalfa	11,700	4.56	2.8	32,760	12.92	423,259
Pasture	67,522	26.33	.....	.....	.....	.....

soil treatment were practiced. Such soils are unproductive for varying reasons and no general treatments can be recommended for their reclamation. Occasionally the difficulty is due to inadequate drainage. In other cases the soils may be in poor physical condition and in need of organic matter or lime. Erosion may occur to some extent in the rough areas and prevent the best utilization of the soils. Special methods of soil treatment must usually be followed for individual conditions and in a later section of this report suggestions will be made regarding the treatment most desirable on the various soil types found in the county. Where conditions are more or less abnormal, the Soils Section of the Iowa Agricultural Experiment Station will furnish advice regarding treatments, upon request.

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

Corn is the most important crop in the county, both in acreage and in value. It is grown quite generally on practically all soil types. The average yield in 1921 was 40 bushels per acre. Much larger yields than this are secured in favorable seasons, particularly on the uplands, altho very often heavy yields are also secured on the rich bottomlands of the county. About 60 percent of the corn crop is fed on the farms, the remainder being shipped to Omaha, St. Louis and Kansas City. The practice of hogging down is followed to some extent. Some of the crop is utilized for silage, but in 1921 there were only 54 silos in the county. Corn furnishes the chief grain feed for the cattle, hogs and work stock. The most important varieties of corn grown are Reid's Yellow Dent, Silver Mine and Boone County White. On a few farms, Iowa Gold Mine and Ninety Day corn are grown.

Alfalfa is the second crop in value, occupying an acreage of 11,700 acres. Average yields of 2.8 tons per acre are reported. It is generally believed that spring sowing is preferable, the crop being seeded with a nurse crop, usually oats. It is estimated that about 60 percent of the alfalfa growers do not use a nurse crop. Some prefer fall sowing and apparently have good success. Three or four cuttings of alfalfa are usually secured; sometimes five are obtained. It is very important, in growing alfalfa, that the soil be well drained and when

*Iowa Year Book of Agriculture, 1921.

acid it should be limed. Much of the alfalfa grown is used for feed for the work stock, milk cows and beef cattle. Some farmers, however, are selling alfalfa to outside markets.

The third crop in value in the county is wheat. Both spring wheat and winter wheat are grown, by far the larger acreage being devoted to the winter varieties. Average yields of 18 bushels per acre were reported in 1921. Spring wheat is grown on a small area with average yields reported at 10 bushels per acre. The major portion of the wheat grown is utilized for home consumption, altho corn is shipped to outside markets, principally Omaha.

There is considerable production of hay in the county, timothy and clover making up the most important tame hay crops. There is a small area in wild hay but this acreage is constantly decreasing. Average yields of tame hay amount to 1.7 tons per acre, while the yields of wild hay are estimated at 1.5 tons per acre. Some timothy is grown alone and in the eastern part of the county considerable clover is grown alone. Some of the clover crop is harvested for seed. The hay produced is all fed to stock on the farms and is very apt to be insufficient.

Oats occupies the second largest acreage in the county and in value the crop produced in 1921 ranked fifth. Average yields of oats are estimated at 26 bushels per acre. Oats are grown in practically all rotations, following corn. The Iowa 103 and Iowa 105 are the leading varieties.

Potatoes are grown on practically all farms with average yields of 50 bushels per acre. The potato crop is all utilized for home consumption and there is no sale of the product.

Barley and rye are grown on small areas and are relatively unimportant crops. The grain produced is all used locally.

Sudan grass has been grown to some extent in the county and has given large yields of hay. Average yields of this crop are reported at 2½ to 3 tons per acre. Sudan grass furnishes excellent summer pasturage for cattle, sheep and hogs.

Sorghum is grown on some areas, particularly in the western part of the county and is used for syrup. Insufficient is produced to supply the local demand. Other crops of minor importance include sweet clover, millet, and rape, all of which are used for forage purposes.

Tomatoes, sweet corn and pumpkins are grown on some areas in the vicinity of Glenwood, the crops being sold to the canning factory there. In general the trucking industry has not been developed to any extent, but many other truck crops might be grown very successfully as has been evidenced by their production on small areas.

Apple orchards are maintained on practically all farms and usually a few pear, plum and cherry trees are also found on the farm. The principal varieties of apples grown are the Jonathan, Grimes, Winesap, Ben Davis, Gano and Mammoth Black Twig. The orchards, generally, are not properly taken care of and the yields of apples are not nearly as large as they should be. Grapes are grown in some parts of the county, particularly on the Knox and Marshall soils in the western part and there is some sale of grapes on the local markets.

which are now under way are comparing the value of these two phosphorus fertilizers but the results are not yet conclusive and tests on the individual farms are all that can be recommended at the present time.

THE GEOLOGY OF MILLS COUNTY

The native rock material underlying the soils of Mills county is so deeply buried under the later deposits of glacial till and loess that it has no effect on the soils of the county. Rarely are there any outcrops of rock material and then only at the base of the steeper bluffs.

At least once during the glacial age the county was covered by a great ice sheet and upon its retreat it left behind a mass of till or glacial debris. The covering of this material is extremely variable in thickness, ranging from about 75 feet in the western part of the county where erosion was most effective prior to the deposition of the loess, up to 150 to 200 feet in the eastern part. The upper part of the till is generally yellow and weathered much like the Kansan drift, but the lower part is often darker and may have been deposited by an earlier glacier. Sometimes the drift is composed of yellow to almost red oxidized material, depending upon the extent of oxidation in the lower depths. The drift is a heavy boulder clay, usually yellow in color but often darker and apparently less oxidized. Boulders are found thruout the drift but these are generally small and composed of various mineral materials. Fine and coarse sand also occur. Beneath the layer of boulder clay there is often a layer of silty material of doubtful origin which in turn is underlaid by sand. None of these earlier deposits, however, have any influence on the soil conditions in the county.

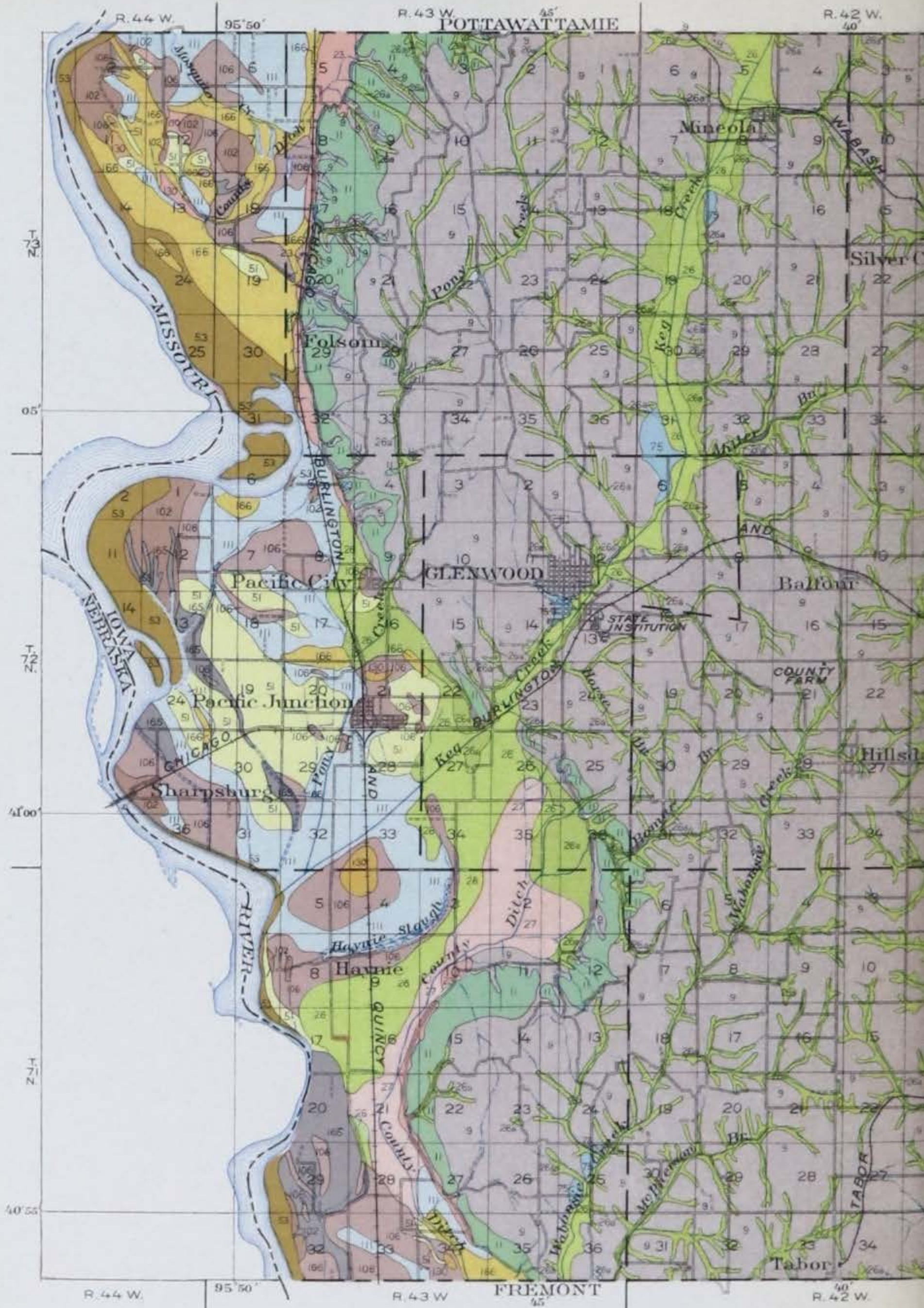
The entire county was covered at some previous geological time, when climatic conditions were very different than at present, by a layer of fine dust-like material known as loess. The average thickness of this loess is estimated at about 60 feet, but along the Missouri river and for several miles to the east of the river, it may reach a thickness of 100 to 150 feet. On the terrace land and bottoms the thickness is much less, ranging from 5 feet to 30 or 40 feet. In color the loess is a grayish-yellow to yellowish-brown. It is an even grained material composed mainly of silt and it has the property of standing in straight cuts, which is characteristic of all loess. Calcareous concretions occur commonly in many localities but due to the weathering to which the material has been subjected since its deposition, the content of lime has been very largely removed and in most of the eastern part of the county the surface soil shows no lime. In the western part, however, the soil on the bluffs is high in lime and in many areas the subsoil is well supplied.

The accumulation of plant remains which has occurred thruout the more gently rolling uplands has led to a darkening of the surface soil and typically the soil is now dark brown in color. The typical yellow of the original loess is found in the lower layers. The soil type known as the Marshall silt loam is the chief upland loess soil in the county covering over one-half of the total area, and this type has become darkened in color and in many instances it has lost most or all of its lime content. The soil on the bluffs in the western part of the county is the Knox silt loam and it is light in color and rich in lime. The terrace

SOIL MAP OF

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

Soils surveyed by Grove B. Jones
in charge, and N. J. Russell of



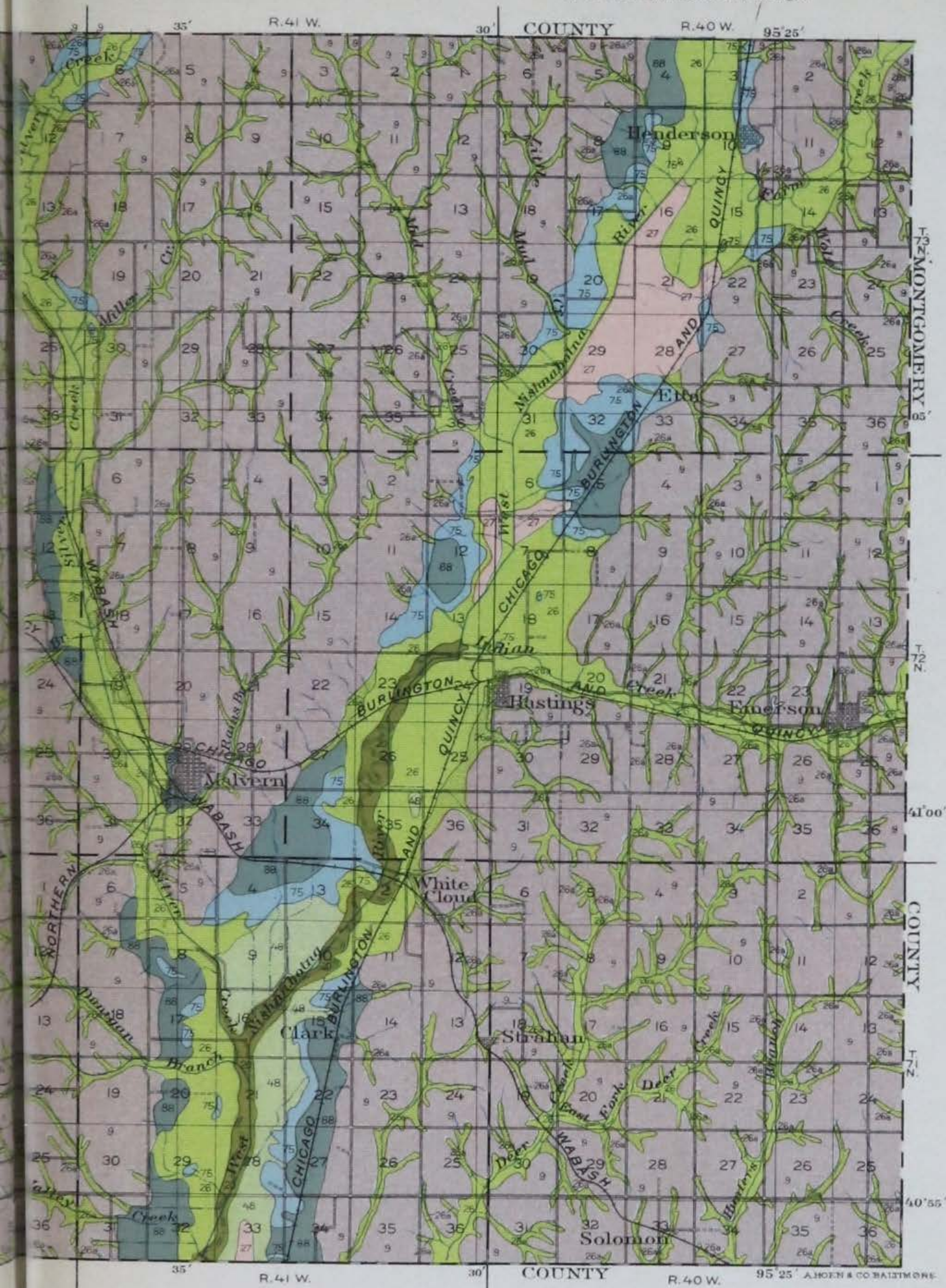
LOESS SOILS		TERRACE SOILS		SWAMP AND	
9	Marshall silt loam	85	Bremer silt loam	26	Wabas
11	Knox silt loam	75	Waukesha silt loam	26a	Wabas (colluv)
		23	Hancock silt loam	III	Lamou

Scale: 1

HILLS COUNTY

U. S. Department of Agriculture,
Agricultural Experiment Station.

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



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106	Cass silt loam	48	Wabash silty clay loam
27	Wabash silty clay	165	Cass clay
51	Cass silty clay loam	20	Meadow
166	Lamoure clay	102	Sarpy fine sandy loam
53	Riverwash	130	Cass fine sandy loam

A. HOEN & CO. BALTIMORE

and bottomland soils in the county are all derived from the loess and have been modified in various ways by the method of formation or deposition. They are largely dark in color and many are low in lime.

PHYSIOGRAPHY AND DRAINAGE

The topography of Mills county as a whole is gently rolling to smoothly rolling. Bordering the broad flood plains of the Missouri river, however, there is a narrow area of bluffs, some of which are of considerable height with sharply cut ridges and smooth and abruptly retreating slopes. Others have beautifully rounded summits and more gentle slopes. Eastward from these bluffs there is a belt of hilly country averaging about three miles in width. In some of this belt the surface is much dissected and too steep for cultivation. These bluffs and the adjacent hilly country are covered with the Knox silt loam.

To the east of the bluffs thruout the upland of the remainder of the county, the soil is mapped as the Marshall silt loam and its characteristic topography is smoothly rolling. This type covers over half of the county. The rougher areas of the Knox silt loam on the bluffs occupy less than two percent of the total area of the county and hence the soil is of much less importance.

The Marshall silt loam on the uplands is cut by the rather shallow valleys of the various streams and their tributaries and the slopes are gentle and uniform. The crests of the divides between the streams are smooth and rounded and the whole appearance of the county east of the bluffs is gently undulating to rolling.

The bottomlands of the county include the rather wide areas along the Missouri river and the narrower strips bordering the streams in the eastern part of

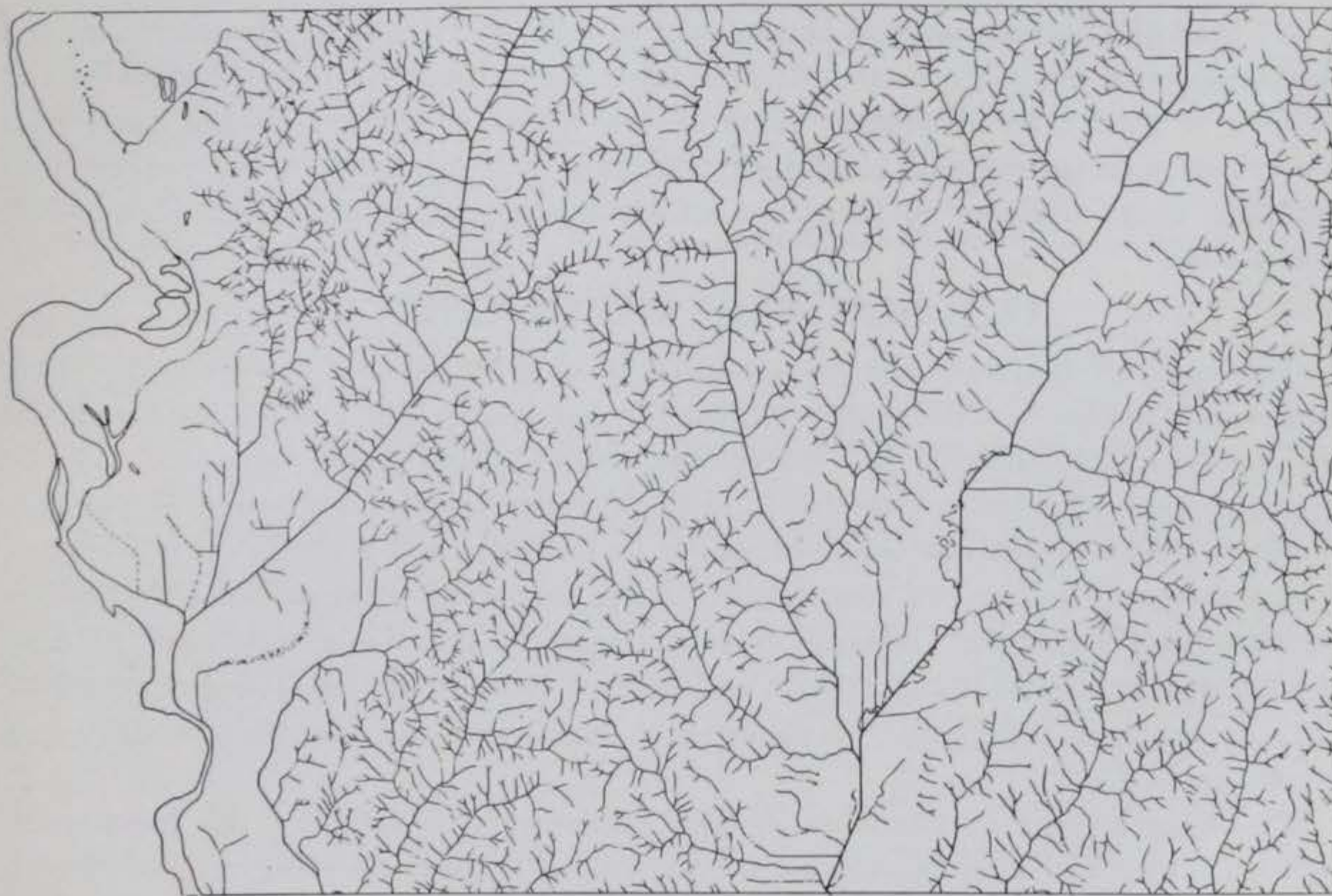


Fig. 2. Map showing natural drainage system of Mills County.

the county. All are level to flat in topography. Terraces occur along the West Nishnabotna river, Silver creek and in smaller areas along Keg and Wabonsie creeks. There are none along the Missouri river. These terraces have a level to gently sloping topography.

The drainage of the county is brought about by the Missouri river and its tributaries in the western part of the county and by the West Nishnabotna river and its tributaries in the eastern part. The chief tributaries of the latter river are Indian creek, which drains the greater part of the township of the same name and Silver creek which drains the north central part of the county.

The Missouri river flows in a general southerly direction and the middle of the channel is the western boundary of Mills county as well as the boundary between Iowa and Nebraska. The river frequently changes its course and considerable areas are constantly being washed away. The boundary line of the county is therefore constantly changing. The valley of the river in Mills county is approximately three and one-half miles in width at the northern and southern county lines and the greatest width is reached just south of Pacific Junction where it is about six and one-half miles wide. The bottoms of the other rivers and creeks in the county are comparatively narrow and are subject to overflow.

There are numerous intermittent drainageways extending thruout the uplands and joining the various streams and these bring about a quite adequate drainage of the uplands. Many of the tributary streams to the larger rivers and creeks are small and shallow and little more than draws, in which water flows only following heavy rains. Much of the bottomland along the Missouri river is not subject to overflow, or at least is flooded only at times of heavy floods. Drainage of these areas is, however, less adequate and the control of moisture is a more difficult matter.

At least the eastern part of the county is quite satisfactorily drained, and the accompanying drainage map indicates that the natural drainage system of the county is good. By dredging, some of the winding stream courses have been converted into deeper and straighter channels and overflows of the narrow bottomland areas adjacent to them are, as a consequence, relatively of rare occurrence now.

THE SOILS OF MILLS COUNTY

The soils of Mills county are grouped into three classes according to their origin and location. These groups are the loess soils, the terrace soils and the swamp and bottomland soils. Loess soils are fine dustlike deposits made by the wind at some time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the stream which deposited them or by a deepening of the river channels. Swamp and bottomlands are those occurring in low, poorly drained areas along streams and subject to more or less frequent overflow. The extent and occurrence of these three groups of soils in Mills county are shown in table II.

The largest part of the county, 60.3 percent, is covered by the loess soils. The swamp and bottomland soils are second in extent, covering 35 percent of the total area. The terrace soils are of minor occurrence, together covering only 4.7 percent.

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

Soil group	Acres	Percent of total area of county
Loess soils	166,016	60.3
Terrace soils	12,800	4.7
Swamp and bottomland soils	96,384	35.0
Total	275,200	....

There are fifteen individual soil types and these with the colluvial phase of the Wabash silt loam and the areas of riverwash and meadow make eighteen soil areas in the county. There are two loess soils, three terrace soils and thirteen areas of bottomland soils. These various soil types are distinguished on the basis of certain definite characteristics which are discussed in the appendix to this report. The areas covered by the various soil types are shown in table III.

The Marshall silt loam is the largest individual soil type, covering 58.4 percent of the total area of the county. The Wabash silt loam with the colluvial phase which is somewhat more extensive than the typical soil, covers the second largest area, 21.8 percent. The remaining soil types are all of small occurrence, the Lamoure silty clay loam, the Bremer silt loam and the Cass silt loam covering 2.6, 2.4 and 2.2 percent, respectively. The Knox silt loam and the Waukesha silt loam cover 1.9 percent, the Wabash silty clay, 1.8 percent, the Cass silty clay loam 1.4 percent, the Lamoure clay, 1.2 percent and the riverwash 1.1 percent. The other soil types all cover less than one percent of the county.

There is a relation between the topography of the land and the soil types, at least as far as the uplands are concerned. The Knox silt loam occurs in the hilly section of the county and the topography is rough to hilly and steep with some areas of more rolling land. The Marshall silt loam on the other hand has

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN MILLS COUNTY

Soil No.	Soil type	Acres	Percent of total area of county
LOESS SOILS			
9	Marshall silt loam	160,832	58.4
11	Knox silt loam	5,184	1.9
TERRACE SOILS			
88	Bremer silt loam	6,528	2.4
75	Waukesha silt loam	5,184	1.9
23	Hancock silt loam	1,088	0.4
SWAMP AND BOTTOMLAND SOILS			
26	Wabash silt loam	25,344	21.8
26a	Wabash silt loam (colluvial phase)	34,560	
111	Lamoure silty clay loam	7,104	2.6
106	Cass silt loam	6,016	2.2
27	Wabash silty clay	4,864	1.8
51	Cass silty clay loam	3,904	1.4
166	Lamoure clay	3,200	1.2
53	Riverwash	3,072	1.1
48	Wabash silty clay loam	2,560	0.9
165	Cass clay	1,856	0.7
20	Meadow	1,728	0.6
102	Sarpy fine sandy loam	1,728	0.6
130	Cass fine sandy loam	448	0.1
	Total	275,200	

a gently rolling to undulating topography. The terraces and bottomlands are all quite level in topography and the latter types are often in need of drainage. The Bremer soils on the terraces are more depressed in topography than the Waukesha and Hancock soils but the topographic differences are not distinctive in many areas.

THE FERTILITY IN MILLS COUNTY SOILS

Samples were taken for analysis from all the soil types in the county. The areas of riverwash and meadow were not sampled as they are so variable in composition that a knowledge of their composition, or at least of the composition of any sample, would mean little. The more extensive soil types were sampled in triplicate but only one sample was taken from each of the minor types. All samplings were made with the greatest care that the samples should be thoroly representative of the soil types and that all variations due to local conditions or 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 official methods were used for the phosphorus, nitrogen and carbon determinations and the limestone requirement determinations were made by the Truog qualitative test. The figures given in the tables are the averages of the results of duplicate determinations on all samples of each type. They represent therefore, the averages of four and 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.

The phosphorus content of the soils of the county is quite variable, ranging from 821 pounds in the Cass fine sandy loam up to 2,450 pounds in the Hancock silt loam. There seems to be no relation between the content of phosphorus and the soil groups, altho the average of the bottomland types and also of the terrace soils is somewhat better than that of the upland soils. This might be expected as bottomland soils are cropped to a lesser extent and hence there is a smaller removal of plant food constituents. The upland soils have about the same content of phosphorus, but there are some rather wide variations in the amount of phosphorus in the individual soils in the other groups. Indeed in general the variations within groups are much wider than those between the various groups.

There seems to be some relation between the phosphorus content of the individual soils and the particular soil type. Thus the Hancock silt loam and the Bremer silt loam on the terraces are higher than the Waukesha. The Wabash and Lamoure types on the bottoms are better supplied than the Cass and Sarpy soils. The differences in some cases are not very large however and conclusions are difficult.

The effects of soil texture are not very well shown by the soils in this county as they are mostly all silt loams. The Lamoure silty clay loam, however, is richer in phosphorus than the clay; the Cass clay and silty clay loam are much

TABLE IV. PLANT FOOD IN MILLS COUNTY, IOWA SOILS
Pounds Per Acre of Two Million Pounds of Surface Soil (0-6 2-3").

Soil No.	Soil type	Phosphorus	Nitrogen	Organic carbon	Inorganic carbon	Limestone requirement
LOESS SOILS						
9	Marshall silt loam	1,526	2,626	26,605	0	4,000
11	Knox silt loam	1,508	1,920	16,968	21,784	0
TERRACE SOILS						
88	Bremer silt loam	1,777	4,480	48,648	0	6,000
75	Waukesha silt loam	1,212	3,440	35,326	0	4,000
23	Hancock silt loam	2,450	3,320	38,001	0	2,000
SWAMP AND BOTTOMLAND SOILS						
26	Wabash silt loam	1,575	2,600	31,449	0	4,000
26a	Wabash silt loam (colluvial phase)	1,669	4,320	44,499	0	3,000
111	Lamoure silty clay loam	2,087	3,200	33,142	0	2,000
106	Cass silt loam	1,400	3,020	35,954	0	2,000
27	Wabash silty clay	1,589	2,240	30,903	0	3,000
51	Cass silty clay loam	1,510	3,660	43,515	0	3,000
166	Lamoure clay	1,709	2,880	33,565	7,494	0
48	Wabash silty clay loam	1,642	2,780	65,028	0	3,000
165	Cass clay	1,709	4,240	41,042	3,073	0
102	Sarpy fine sandy loam	1,441	1,280	52,179	15,180	0
130	Cass fine sandy loam	821	1,280	16,979	1,858	3,000

better supplied than the fine sandy loam, but there is very little difference between the amounts in the Wabash silt loam and in the silty clay loam and the silty clay. In general it has been observed that soils which are coarse in texture are lower in plant food and those which are fine in texture are better supplied. That conclusion seems to be borne out by these results as far as conclusions are possible. The differences in characteristics of the soil series are often of the most importance and the color, topographic position, origin or other characteristic which determines the soil series may indicate quite definitely the content of phosphorus and other plant food. In all cases however the texture is of large significance.

The results of the analyses as a whole indicate that the supply of phosphorus in the soils of the county is not large and while it cannot be said that the element is deficient in any case, yet the amount is so low that there is evidence that phosphorus fertilizers will certainly be needed in the near future if crops are to be properly supplied. Furthermore it is quite probable that additions of phosphorus now might give profitable effects, for as the total content of an element decreases in a soil, the supply of that element in an available form decreases very rapidly and it is quite likely that phosphorus is not being changed into an available form rapidly enough in many cases.

The total content of phosphorus in soils does not indicate how much may be made available for plant use but if the total amount is low, it can be quite definitely concluded that there will be a deficiency in the supply of the constituent in an available form. If the supply of the element is large, availability may

be low, but there is much more chance for the proper change of the element into an available form.

The amount of phosphorus present in the soils of Mills county is such that in many cases phosphorus fertilizers would probably prove profitable at the present time. In any case these materials will be needed in the near future. There are some indications of value from the use of phosphatic materials as will be pointed out in later pages in this report, but the results which have been secured to date are not definite enough to permit of recommending the use of phosphorus on individual soil types. It is urged, therefore, that farmers test the use of phosphorus on their own soils, and by applying acid phosphate and rock phosphate to small areas they may determine, not only the value of phosphorus on their soils but also which fertilizer should be used.

In nitrogen content, the soils of the county are quite variable. They range from 1,280 pounds in the Cass fine sandy loam up to 4,480 pounds in the Bremer silt loam. On the average, the terrace and bottomland types seem to be somewhat better supplied than the upland soils but the differences are not large.

The effects of soil texture on the nitrogen content are not very clearly shown in these results as only in a few cases are there types of different texture in the same series represented in the county. The Cass fine sandy loam is much lower than the other types of the Cass series which are much heavier in texture. The differences among the soils in the Wabash series are however, very slight and indeed the colluvial phase of the Wabash silt loam is higher in nitrogen than the other Wabash types of heavier texture. In general however, the nitrogen supply is greater in soils which are fine textured.

Other characteristics upon which soil series are differentiated also have an important effect upon the nitrogen content. Thus the color is significant. The Marshall silt loam is higher in nitrogen than the Knox silt loam which is lighter in color. The Waukesha silt loam is lower than the Bremer silt loam which is darker in color. No comparisons are possible among the bottomland types. The topographic position is likewise of importance. Thus the more level or gently rolling Marshall on the upland is richer in nitrogen than the steeper or rougher Knox. The level to depressed Bremer on the terrace is higher in nitrogen than the more gently rolling Waukesha. There is usually quite a definite relation between the nitrogen supply in soils and their color, their topographic position and their texture and the analyses of the soils of this county confirm previous indications along this line.

The supply of nitrogen in these soils is not very low in most cases, but in spite of this fact, nitrogen must not be overlooked in planning systems of permanent fertility. Nitrogen is constantly being removed from soils by crops and by leaching and if the supply is to be kept up some means must be employed to return to the soil the amounts of this element which are removed. Farm manure is the most commonly used fertilizer and it serves to return much of the nitrogen removed by crops, provided the manure is properly stored and applied to the soil. The soils of this county respond to applications of farm manure, not only in the case of those types which are not so well stocked with the element but also in the case of the soils which are apparently well supplied. On the richer soils smaller amounts may be used with profit but on all the soils of the county the

use of farm manure is most desirable and when it is used the problem of keeping up the nitrogen content is less difficult.

Crop residues also aid materially in maintaining the supply of nitrogen in soils and these materials should be used and not destroyed as is often the case.

On many farms, there is not sufficient farm manure to supply all the soils and where this is true, or on grain farms where farm manure is not produced, the nitrogen supply of the soils must be kept up by some other means. In such cases the use of leguminous crops as green manures is to be recommended. When well inoculated, legumes use the free nitrogen of the atmosphere, at least in part, and hence if the entire crop or a large part of it is turned under in the soil, there may be a considerable addition of nitrogen to the soil. If the entire crop of the legume is removed from the soil then there will be no addition of nitrogen, on the average soil, as the amount of the element in the roots of such legumes as red clover and alfalfa is almost exactly equal to that taken from the soil, while the amount in the tops represents that taken from the air. If the farm manure is thoroly utilized, the crop residues are all turned under in the soil and legumes are utilized as green manures, then it is possible to keep up the nitrogen content of soils and it is not necessary to use commercial nitrogen.

The amount of organic matter in soils is indicated by the content of organic carbon. It is also indicated by the color of the soils. Thus black soils are high in organic matter while light colored types are low in this constituent. There is therefore usually quite a definite relation between the organic matter content and the content of nitrogen. Black soils are higher in nitrogen than light colored types. It may generally be safely assumed that soils which are high in organic matter are well supplied with nitrogen.

The relation between the organic carbon and the nitrogen indicates fairly accurately the rate at which the plant food in the soil is being made available. This ratio in most of the Mills county soils is not very satisfactory, and in many cases some means should be employed to increase the production of available plant food in the soils. Thus in the Marshall silt loam, the Bremer silt loam and the majority of the bottomland types it is desirable to stimulate the availability processes. Farm manure is of particular value on these soils as it has the ability to bring about an increase in plant food production because of the bacterial content. Further evidence is thus given of the importance of applying farm manure to the soils of the county in order to provide for the best supplying of plant food in an available form to crops.

The organic carbon content of the soils of the county is quite variable and the relations between this constituent and the soil types is much the same as in the case of the nitrogen. The heavy textured soils, more level in topography and dark in color, are higher than the fine textured, more rolling, lighter colored types. The relationship between soil type and soil series and the carbon content is quite definitely shown.

The maintenance of the supply of organic carbon or organic matter in the soils of the county is very important as the supply of this constituent constantly decreases. In a few cases it is quite desirable to increase the supply. The use of farm manure, crop residues and leguminous green manures will permit of the keeping up of the organic matter content and these materials should be used

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

Pounds per Acre of Four Million Pounds of Subsurface Soil (6 2-3"-20").

Soil No.	Soil type	Phosphorus	Nitrogen	Organic carbon	Inorganic carbon	Lime-stone requirement
LOESS SOILS						
9	Marshall silt loam	2,738	3,600	47,928	0	4,660
11	Knox silt loam	2,694	2,320	31,636	50,300	0
TERRACE SOILS						
88	Bremer silt loam	2,236	5,760	59,841	0	4,000
75	Waukesha silt loam	2,154	3,600	54,927	0	4,000
23	Hancock silt loam	3,878	4,400	56,128	0	2,000
SWAMP AND BOTTOMLAND SOILS						
26	Wabash silt loam	3,124	3,760	48,703	0	4,000
26a	Wabash silt loam (colluvial phase)	3,904	6,720	97,724	0	2,000
111	Lamoure silty clay loam	3,178	3,680	37,575	8,070	0
106	Cass silt loam	2,625	4,480	40,308	7,302	0
27	Wabash silty clay	2,558	2,400	35,926	0	3,000
51	Cass silty clay loam	2,572	4,120	35,844	4,996	0
166	Lamoure clay	3,500	4,960	44,513	17,294	0
48	Wabash silty clay loam	2,706	5,160	75,566	0	3,000
165	Cass clay	2,694	4,720	37,714	2,690	0
102	Sarpy fine sandy loam	2,640	480	5,705	24,980	0
130	Cass fine sandy loam	1,778	1,360	3,311	13,833	0

properly on all the soils of the county. When this is done the soils may be built up and kept up in organic matter.

The surface soil of the Marshall silt loam does not show any content of inorganic carbon and the tests indicated a lime requirement. The samples tested were typical of the soil in the county and only infrequently is this soil type high in lime content. Occasionally a small area will be found where lime concretions occur in the surface soil. The Knox silt loam is practically always high in inorganic carbon in the surface soil and on down thru the subsoil. The terrace soils are all acid in the surface layers and the bottomland types of the Wabash series and some of the Cass and Lamoure types do not show a lime content in the surface soil. The Lamoure clay, the Sarpy fine sandy loam, the Cass clay and the Cass fine sandy loam show a rather considerable content of inorganic carbon.

The lime requirement of the surface soils of the county is indicated as being generally quite small. The figures given in the table should be considered merely indicative of the needs of the soils of the county however, as soils vary widely in lime requirement and variations will often occur even in samples from the same field and frequently in soils of the same type. Every soil should be tested before lime is applied in order that a proper application may be made. It may be concluded that except for the Knox silt loam, all the upland soils and all the terrace types in the county and also some of the bottomland types may be acid in reaction and in need of lime if the best growth of crops particularly legumes

is to be secured. Even if the acidity is only slight, small applications of lime may be very desirable in securing a good initial crop growth. The amount to be used must always be determined in each individual case.

THE SUBSURFACE SOILS AND 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 soils and 6,000,000 pounds of subsoil per acre. Unless large amounts of plant food are present in the lower soil layers, there is little effect on the fertility of the soil. The analyses of the surface soils therefore usually indicate quite definitely the needs of the soils and the conclusions drawn are not modified to any extent by a study of the analyses of the lower soil layers.

The subsurface soils and subsoils in Mills county are not rich in any of the plant food constituents; in general they are not as high as the surface soils and hence fertility is not affected to any extent by the subsoil conditions. It is not necessary to consider these analyses in detail and it may merely be mentioned that they serve to confirm the conclusions drawn from the analyses of the surface soils.

Many of the soils are well supplied with lime in the lower layers. The Hancock silt loam on the terraces and the Lamoure and Cass and Sarpy soils on the bottoms are all high in lime. The Knox silt loam on the upland is rich in lime and in some cases the Marshall silt loam shows a lime content in the subsoil.

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

Pounds Per Acre of Six Million Pounds of Subsoil (20"-40")

Soil No.	Soil type	Phosphorus	Nitrogen	Organic carbon	Inorganic carbon	Limestone requirement
LOESS SOILS						
9	Marshall silt loam	4,134	4,000	32,074	22,635	3,000*
11	Knox silt loam	4,242	1,920	19,650	68,838	0
TERRACE SOILS						
88	Bremer silt loam	2,667	6,240	58,640	0	4,000
75	Waukesha silt loam	2,787	9,240	72,727	0	4,000
23	Hancock silt loam	4,686	3,840	40,122	16,716	0
SWAMP AND BOTTOMLAND SOILS						
26	Wabash silt loam	3,999	6,720	81,244	0	3,000
26a	Wabash silt loam (colluvial phase)	3,879	6,480	94,676	0	3,000
111	Lamoure silty clay loam	4,767	3,480	54,657	27,786	0
106	Cass silt loam	3,777	2,760	31,009	25,748	0
27	Wabash silty clay	4,566	2,880	30,576	0	2,000
51	Cass silty clay loam	3,109	2,520	36,378	17,102	0
166	Lamoure clay	5,778	7,680	74,466	11,529	0
48	Wabash silty clay loam	3,615	5,220	55,145	0	2,250
165	Cass clay	2,826	1,320	8,940	18,906	0
102	Sarpy fine sandy loam	3,717	600	10,065	31,704	0
130	Cass fine sandy loam	2,826	1,080	28,501	0	0

*One sample showed acidity.



Wheat and clover on Cass silt loam.

On these types the need of lime in the surface soils will not be modified however, as lime rarely moves upward in the soils and there is a continual washing away of the lime content in the drainage water. If the surface soil shows acidity, then a lime application is necessary for the best legume growth in spite of the lime content in the subsoil. It is necessary therefore that the soils of the county, except the Knox types, should be tested for lime needs, just as was concluded in the discussion of the analyses of the surface soils.

GREENHOUSE EXPERIMENTS

One greenhouse experiment was carried out on a soil from Mills county, the Cass silt loam being used for the purpose. Results from greenhouse experiments with the Marshall silt loam from Montgomery county are also included as the soil type is the same and the conditions are practically identical in the two counties. These greenhouse tests indicate something of the needs of the soils and show the value of various fertilizing materials.

The treatments used include manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. The amounts of these materials used are the same as are used in the field tests and in practice. Manure was added at the

TABLE VII. GREENHOUSE EXPERIMENT
Cass Silt Loam—Mills County

Plot No.	Treatment	Wheat grain in grams	Clover, weight in grams
1	Check	8.60	52.0
2	Manure	11.41	70.0
3	Manure+Lime	11.18	87.0
4	Manure+Lime+Rock phosphate	11.82	89.0
5	Manure+Lime+Acid phosphate	12.33	76.0
6	Manure+Lime+Complete commercial fertilizer	13.34	70.0

TABLE VIII. GREENHOUSE EXPERIMENT
Marshall Silt Loam, Montgomery County, 1918

Plot No.	Treatment	Weight of clover in grams
1	Check	59.0
2	Manure	62.5
3	Manure+Lime	62.0
4	Manure+Lime+Rock phosphate	62.0
5	Manure+Lime+Acid phosphate	70.5
6	Manure+Lime+Complete commercial fertilizer	66.5

rate of eight tons per acre, lime in sufficient amounts to neutralize the acidity of the soils and supply two tons additional. Rock phosphate was used at the rate of one ton per acre, acid phosphate at the rate of 200 pounds per acre, and a standard 2-8-2 brand of a complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in the experiments, the clover being seeded about one month after the wheat was up. Only the clover yields are given in one of the tests on the Marshall silt loam samples from Montgomery county as the wheat yields were not secured in that case.

The results on the Cass silt loam from Mills county are given in table VII. The application of manure gave a distinct increase in the wheat yield and also in the yield of the clover. Lime in addition to manure had no effect on the wheat but gave an increase in the clover. This is what would be expected as wheat is not sensitive to small amounts of acidity, while clover is not apt to grow nearly so well if the soil is acid. The rock phosphate increased the wheat yield slightly but gave little effect on the clover. The acid phosphate and the complete commercial fertilizer gave distinct increases in the wheat but showed no effect on the clover. It seems evident from these results that manure will prove of value on this type even if it is not very low in organic matter content. Lime may prove of value on legumes and phosphates may give results on the small grain crops. They may also prove effective on legumes, altho no effect was indicated in this test on the clover. Tests in the field of the value of these materials are certainly very desirable.

The results of the test on the Marshall silt loam from Montgomery county in 1918 are given in table VIII. Manure brought a distinct increase in the clover, but the lime had no additional effect. This sample was not highly acid in reac-



Fig. 4. Clover pot culture on Marshall silt loam indicated the value of manure.

TABLE IX. GREENHOUSE EXPERIMENT
Marshall Silt Loam, Montgomery County, 1919

Plot No.	Treatment	Weight of wheat in grams	Weight of clover in grams
1	Check	15.25	83.9
2	Manure	15.75	90.7
3	Manure+Lime	16.00	88.4
4	Manure+Lime+Rock phosphate	18.50	97.5
5	Manure+Lime+Acid phosphate	17.00	104.3

tion and the lime did not prove necessary. On many other samples of the Marshall, however, lime does prove of value, and when the type is acid lime should be used in order to insure good crops of legumes. The rock phosphate with the manure and lime had no effect but the acid phosphate and the commercial fertilizer both brought about decided increases in the clover. The acid phosphate showed a very large influence. It is evident that manure is a particularly valuable fertilizer for this soil and the indications are that a phosphate might also be used with profit.

The results of the tests on the same soil type from Montgomery county in 1919 are given in table IX. The application of manure gave a slight effect on the wheat but showed a distinct influence on the clover. Lime increased the wheat yield slightly but had no effect on the clover. Rock phosphate and acid phosphate both gave large increases in the wheat yields and particularly large gains in the clover crop. The yields with the complete fertilizer are not given as the crops were injured in those pots. The relative effects of the two phosphates in this test are of interest as the acid phosphate gave much larger effects than the rock on the clover but the reverse was true on the wheat. No definite conclusions should be drawn from these tests however, as the differences are not distinctive enough and there are not enough results. It is quite possible however that the two materials may prove of different value on different crops. The effects are evidently different also on various soils.

Apparently the Marshall silt loam will respond to applications of farm manure and phosphates may prove of considerable value. In other cases the use of lime may be very desirable when the soil is acid, in order to insure the best growth of legumes. Tests of rock and acid phosphate on this soil type are recommended, in order to learn the need of the particular soil for phosphorus and also to learn which material should be employed.

FIELD EXPERIMENTS

A field experiment has been laid out in Mills county but thus far results have not been secured and hence no data are available from field work in this county. The test must be carried on for a period of years before the results will be of any value and capable of interpretation. The data secured will be published later in a supplementary report. Several experiments under way in other counties, however, have been yielding results for several years and they are located on the Marshall silt loam, the chief type in Mills county, and hence these results may be considered as applicable to that type in Mills county and will be presented. In addition the average results from all the field experiments on the Marshall silt loam in the state will be presented and discussed.

TABLE X. VILLISCA FIELD EXPERIMENT
Marshall Silt Loam—Montgomery County. Villisca Field

Plot No.	Treatment	1918 clover T. per acre	1919 corn bu. per acre	1920 oats bu. per acre	1921 clover lbs. per acre	1922 corn bu. per acre
1	Check	1.0	49.3	46.2	1477	64.1
2	Manure	1.2	51.0	52.1	1772	73.9
3	Manure+Lime	1.3	50.3	52.7	1990	76.6
4	Manure+Lime+Rock phosphate	1.5	52.0	54.7	2254	81.1
5	Manure+Lime+Acid phosphate	1.4	49.0	72.7	1601	80.3
6	Manure+Lime+Complete commercial fertilizer	1.6	48.7	58.1	2083	82.4

The individual experiments reported have been carried out on the Marshall silt loam on the Villisca field in Montgomery county, on the Red Oak field in the same county and on the Avoca field in Pottawattamie county. These fields are all laid out on land which is thoroughly representative of the soil type. The plots are 155' 7" by 28', or one-tenth of an acre in size. The location of the plots is fixed by corner stakes. All precautions are used in the application of fertilizing materials and in the securing of the crop yields in order that the results may be considered quite dependable.

Each series of plots includes tests under the livestock system of farming and under the grain system, but only the results on the livestock plots are included here inasmuch as the grain system plots have not proven very satisfactory. Manure is applied to the livestock system plots at the rate of eight tons per acre once in a four-year rotation. Lime is added in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is added at the rate of one ton per acre once in four years and acid phosphate at the rate of 200 pounds per acre annually. A standard complete fertilizer, a 2-8-2 brand, is applied at the rate of 300 pounds per acre annually. During the past year, the new standard, 2-12-2 brand has been substituted for the old standard and an application of 267 pounds per acre has been made, thus supplying the same amount of phosphorus as that contained in the acid phosphate.

THE VILLISCA FIELD

The results obtained on the Villisca field in Montgomery county are given in table X. Examining these results, it is evident that manure has brought about a distinct increase in all the crops grown. The effect is particularly noticeable on the clover in 1921 and on the corn in 1922. The application of lime in addition to manure had some effect on the clover in 1918 and again in 1921. There was also some influence on the corn in 1922. The rock phosphate gave increases in all cases, the effects being particularly noticeable on the clover in 1921 and on the corn in 1922. The acid phosphate increased the yields in some cases but gave no effects in other years. Increases were pronounced in 1920 on the oats and in 1922 on the corn while in 1919 and 1921 the crop yields were evidently somewhat abnormal and no effects were secured. The complete commercial fertilizer gave increases in all but one case and the effects were about the same as those brought about by the phosphates. Sometimes it proved slightly better

TABLE XI. RED OAK FIELD EXPERIMENT

Marshall Silt Loam—Montgomery County, Red Oak Field

Plot No.	Treatment	1919 corn bu. per A.	1920 corn bu. per A.	1921 oats bu. per A.	1922 wheat bu. per A.
1	Check	52.0	56.0	28.2	13.2
2	Manure	57.2	61.6	36.9	15.5
3	Manure+Lime	59.2	66.0	37.8	18.6
4	Manure+Lime+Rock phosphate	60.0	63.0	35.6	28.6
5	Manure+Lime+Acid phosphate	58.5	62.7	39.4	30.7
6	Manure+Lime+Complete commercial fertilizer	56.2	64.2	36.4	25.4

while in other cases it was not quite so effective. These results indicate the value of manure on this soil and also the value of lime when the soil is acid.

The beneficial effect of phosphorus fertilizers is also indicated. No definite conclusions can be drawn as to the relative value of the two phosphates as the differences are not distinctive enough. Tests of these materials in the field are the only way that the best material can be chosen for any particular conditions. The complete commercial fertilizer does not seem to be any more desirable for use than the phosphates.

THE RED OAK FIELD

The results obtained on the Red Oak field in Montgomery county are given in table XI. The wheat yields in 1918 are not included owing to very evident abnormality. Again the beneficial effects of the manure is very clearly shown on all the crops. Lime in addition to the manure proved of value in all cases, altho the increases were not very large. It would not be expected that lime would show any large effects however on corn and small grains, and no legume crop yields are included in these results.

The rock phosphate gave increases in practically all cases but no large gains, except in the case of the wheat in 1922. The acid phosphate showed some beneficial effects, particularly on the oats in 1921 and on the wheat in 1922. The complete commercial fertilizer gave increases which were very similar to those brought about by the phosphates, showing up less effectively however than the acid phosphate in 1921 and 1922. These results confirm those secured on the Villisca field, in showing the beneficial effect of manure, lime and phosphorus on the Marshall silt loam. Tests of phosphorus fertilizers in the field are very desirable.

TABLE XII. AVOCA FIELD EXPERIMENT

Marshall Silt Loam—Pottawattamie County. Avoca Field

Plot No.	Treatment	1919 corn bu. per A.	1920 oats bu. per A.	1921 clover tons per A.	1922 corn bu. per A.
1	Check	72.2	59.5	2.00	51.9
2 & 3	Manure	73.1	69.0	2.65	53.8
4	Manure+Rock phosphate	77.8	58.8	2.70	55.5
5	Manure+Acid phosphate	79.3	69.0	2.50	56.5
6	Manure+Complete commercial fertilizer	77.5	61.2	2.80	57.5

THE AVOCA FIELD

The results obtained on the Avoca field in Pottawattamie county are given in table XII. After the first year of the test, the application of manure gave distinct increases in the crop yields, being particularly effective on the oats in 1920. Rock phosphate increased the corn in 1919 and the same crop in 1922 but had no effect on the oats in 1920 and little influence on the clover in 1921. The acid phosphate gave some small increases on the corn crops but had little effect on the other crops. The commercial fertilizer gave some evidence of increasing the yields but the results were not distinctive and were very similar to those secured with the phosphates. No lime was applied to this soil as the type did not show acidity in this test. The results confirm in a general way those discussed previously and show the value of manure on the soil. There are also indications of value from the use of phosphorus fertilizers. Tests in the field are evidently very desirable.

AVERAGE RESULTS OF FIELD EXPERIMENTS ON THE MARSHALL SILT LOAM

The average results of all the field experiments on the Marshall silt loam in the state are given in table XIII. The check or untreated plot averages are calculated from the yields on the three check plots in each field, and averages are struck from the check yields on all the fields. The corn yields are averaged from four crops on four fields, the clover from one crop on one field, the oats

TABLE XIII. MARSHALL SILT LOAM

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

Treatment	Corn*		Oats*		Clover*		Winter Wheat*	
	Av. yield Bu. per A.	Increase for treatment. Bu. per A.	Av. yield Bu. per A.	Increase for treatment. Bu. per A.	Av. yield T. per A.	Increase for treatment. T. per A.	Av. yield Bu. per A.	Increase for treatment. Bu. per A.
Check	58.4	....	35.8	....	1.33	....	15.3	....
Manure	63.4	5.0	42.3	6.5	1.40	0.07	15.5	0.2
Manure+Lime	65.7	7.3	44.4	8.6	1.60	0.27	18.6	3.3
Manure+Lime+Rock phosphate	70.2	11.8	45.8	10.0	2.80	1.47	28.6	13.3
Manure+Lime+Acid phosphate	71.6	13.2	48.8	13.0	3.40	2.07	30.7	15.4
Manure+Lime+Complete commercial fertilizer	69.4	11.0	52.0	16.2	2.60	1.27	25.4	10.1
Crop residues	59.3	0.9	43.5	7.7	1.50	0.17	16.4	1.1
Crop residues+Lime	63.0	4.6	43.8	8.0	2.20	0.87	19.5	4.2
Crop residues+Lime+Rock phosphate	67.2	8.8	47.8	12.0	2.70	1.37	23.8	8.5
Crop residues+Lime+Acid phosphate	67.5	9.1	52.0	16.2	2.80	1.47	22.3	7.0
Crop residues+Lime+Complete commercial fertilizer	64.9	6.5	50.8	15.0	2.70	1.37	22.2	6.9

*Corn yields averaged from 4 crops on 4 fields; oats from 4 crops on 4 fields; clover from 1 crop on 1 field and winter wheat from 1 year's results on 1 field.

from four crops on four fields and the wheat from one year's results on one field.

The value of manure on corn, oats, clover and wheat on this soil is clearly shown, the effects being the greatest on the corn and oats. Lime increased the yields of all the crops, particularly the clover and wheat. The phosphates with manure and lime gave distinct increases in all cases but the acid phosphate was superior to the rock phosphate in every instance, the difference being the greatest in the case of the clover. The complete commercial fertilizer had less effect than the phosphates on the corn, clover and wheat but gave somewhat greater effects on the oats, not enough however to make its use profitable. The crop residues showed slight effects on all the crops. Lime with the residues gave pronounced increases. The phosphates both had beneficial effects, but the acid phosphates proved more effective particularly on the oats. The complete fertilizer showed less effect than the acid phosphate in all cases and only with the oats was it better than the rock phosphate.

The Marshall silt loam may evidently be profitably fertilized with manure, lime and phosphorus, acid phosphate proving somewhat better than the rock both in the livestock system with manure and in the grain system with crop residues. The complete commercial fertilizer had less effect than the acid phosphate in practically all cases and cannot be considered as desirable for use on this soil. Lime may be of value on this type when it is acid but as the type may be basic in some cases, lime should not be applied until the soil has been tested and the need of lime shown. Tests on the farm under the particular farming conditions are very desirable in order to choose between rock phosphate and acid phosphate and determine which material will prove the more valuable.

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

The fertilizer needs of the soils of Mills county are indicated by the results given in the preceding pages, on the laboratory, greenhouse and field experiments. The suggestions given are also based on the experience of farmers and no recommendations are made which have not proven to be valuable by considerable practical experience. While the information on the needs of the soils is not complete, there are some suggestions which can be made which will be of aid in increasing and keeping up the fertility of the soils of the county.

It should be emphasized that the suggestions made in this report may all be put in effect on any farm and the tests recommended are very simple and may be readily carried out. Many farmers are conducting simple fertility experiments on their farms and are securing results which are not only of value to themselves but are of considerable interest to others located on the same soil types. The Soils Section is ready to aid farmers who wish to carry out such tests and directions are given in Circular 82 of the Iowa Agricultural Experiment Station. It will be much more satisfactory for a farmer to test the value of rock phosphate and acid phosphate on his own soils by making an application to a small area. It will then be possible to apply the same fertilizer to a large area and be sure of securing profitable returns. Tests of other materials

such as commercial fertilizers may also be desirable, and farmers may readily determine the response which their soils will show to various fertilizing materials.

LIMING

The upland and terrace soils in Mills county, except for the Knox silt loam, are all acid in reaction in the surface soil, and while the need for lime is not necessarily large this material will need to be used on considerable areas in the county if the best crop yields are to be secured. Many of the bottomland soils are likewise acid and also in need of lime. Even tho considerable lime is found in several cases in the subsoil, if the surface soil is acid it may require liming, as lime rarely moves upward in the soil. Furthermore, soils which are intensively cropped tend to decrease in lime content quite rapidly because of losses by leaching and by neutralization of the acids from the decomposing organic matter in the soil.

Lime is of value on soils because it improves the physical, chemical and bacterial conditions. It opens up heavy soils, introducing air and thus stimulating bacterial action and the production of available plant food. It has the opposite effect upon light sandy soils, making them less porous and open and increasing retention of moisture and plant food and decreasing injury by drought. Chemically lime improves soil conditions because it neutralizes the acidity which is produced in the decomposition of organic matter. It also supplies the plant food, calcium, and in the case of some crops this may be very desirable. All beneficial bacterial processes in the soil are stimulated by additions of lime. The decomposition of organic matter does not proceed so rapidly in acid soils, nitrate production is weak, the production of carbon dioxide is diminished, nitrogen fixation is restricted and in general the production of available plant food may be reduced to such an extent that crops will be improperly supplied.

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

Soils should be tested at regular intervals, at least once in a four year rotation. One application of lime will not suffice to keep the soil from becoming acid within a few years, owing to the continuous utilization of the lime and the carrying away in the drainage water. The soil may be tested preceding the growing of the legume crop of the rotation, and then the lime is applied where it is most needed, that is by the legume. In this way the use of a proper amount of lime in the soil may be insured. Further information regarding liming is given in Bulletin 151 and Circular 105 of the Iowa Agricultural Experiment Station.

MANURING

Many of the soils in Mills county are rather poorly supplied with organic matter and while they are not exceedingly deficient there is evidence that some fertilizing materials must be used to build up and keep up the organic matter supply. The application of manure is of particular value in this county as is evidenced by the results secured in the greenhouse and in the field. The experiences of many farmers also show large values from the application of manure. Other fertilizing materials are of much less value and, in fact, generally give little effect if manure is not applied as a basic soil treatment.

On all farms where manure is produced it should be considered a fundamental soil building material and all precautions taken to care for it properly and apply it. Even on soils in Mills county where apparently the supply of organic matter is better, the manure gives strongly beneficial effects. But on those types which are lighter in color and rather deficient in organic matter very large returns are always secured.

Manure is valuable because of its influence on the physical, chemical and bacterial conditions in the soil. Light open soils are made less porous and less subject to leaching and more retentive of moisture. Heavy impervious soils are opened up and better aerated and conditions are improved for bacterial action. Manure contains considerable amounts of the essential plant foods and it therefore exerts a chemical effect on the soil. These plant food constituents in the manure come from the food supplied to the livestock and the manure therefore returns to the soil a large part of the fertility removed by the crops grown and used for feed. It serves to prolong the life of the soil as it delays the time when any one of the essential elements will become deficient. Manure supplies considerable organic matter to soils and this improves the conditions by modifying the bacterial, chemical and physical action.

Bacteria are present in manure in enormous numbers and these organisms by their activities produce available plant food. They use the organic matter contained in the manure as well as that in the soil itself and hence there is a stimulation in the action of the bacteria supplied in the manure as well as in the action of the bacteria already in the soil. The result of this increase in numbers and action of bacteria is a very large increase in available plant food production. Many times the beneficial effects of manure may be due to the improved bacterial conditions but in general it is believed that manure benefits soil by improving the physical and chemical conditions in the soil as well as the bacterial.

Very often manure is so stored that it loses much of its fertility. When stored in uncovered heaps exposed to the weather and the liquid portion is allowed to run away, as much as 90 percent of the valuable constituents of manure may be lost. When this occurs the beneficial effect of the manure on crop growth is correspondingly reduced. Hence the loss from improperly stored manure means actual money losses on the farm. If manure is carefully stored and applied it may return to the land 75 to 80 percent of the plant food removed by the crops grown.

It is evident that precautions should be taken on the farm to prevent losses of manure. It may be stored in a covered yard or pit or in some other manner

protected from undergoing losses. No one method can be recommended for all conditions. In general it may be said that any method which will keep the manure moist and compact and protect it from the weather will prove satisfactory. Even if some expense is involved in properly storing manure it will be well worth while because of the increased crop returns which will be secured from its use.

The usual application of manure is eight to ten tons per acre once in a four year rotation. Larger amounts of manure might frequently be used profitably, but if large applications are made to one field some other portion of the farm must be left untreated, for the production of manure on the average farm is insufficient to permit of large applications to all the land on the farm. There is little danger, therefore, of making too heavy an application of manure provided the manure produced is uniformly distributed over the farm. It is rarely advisable in any case to apply more than 16 to 20 tons for ordinary farm crops and only where garden or truck crops are raised should larger amounts be employed.

GREEN MANURING

Many times the amount of manure produced on the farm is insufficient to meet the soil needs and on the grain farm no manure is produced. In both cases green manuring may be practiced as a supplement to or as a substitute for manuring. Legumes are most desirable for use as green manures because when well inoculated they are able to utilize the nitrogen content of the atmosphere and thus they may act as a nitrogenous fertilizer as well as a source of organic matter and when applied to the soil they have a double value. Non-legumes are sometimes employed for green manuring purposes, but it is generally true that land in need of organic matter is also in need of nitrogen and much better returns will be secured from the use of legumes. There are many legumes which may be utilized as green manures and hence some one may be chosen which will fit in with almost any cropping system on any farm and will be adapted to the particular soil and climatic conditions.

Green manuring might often prove of value in Mills county by increasing the crop yield and making the soil more fertile. It is a practice, however, which must not be followed carelessly nor blindly as it may prove very unsatisfactory if conditions are not at the best. If a soil is too dry the green manure will not be decomposed and there may be an injury to the moisture conditions in the soil. The turning under of a heavy crop in a dry season may lead to very unsatisfactory results. Suggestions regarding green manuring under individual soil conditions will be given by the Soils Section upon request. The second crop of clover is often turned under in the soil and thus may serve as a partial green manuring crop. The clover seed may be removed and the remainder of the clover utilized for green manure. By such practices partial green manuring effects are brought about. Sometimes the legume may be seeded in the corn with the last cultivation. This may also be of some value in improving the fertility of the soil.

A third means by which the organic matter content of the soil may be kept up is by the proper utilization of all crop residues particularly straw and stover. They not only contain organic matter, but they have considerable amounts of

various chemical constituents and hence are of double value when turned under in the soil. Too often these materials are burned or otherwise destroyed and their value is lost. They may be used for feed or bedding and returned to the soil with the manure. This is the common practice on the livestock farm. On the grain farm they may be stored and allowed to decompose partially before they are applied. It is very important, however, that under both systems of farming care be taken to utilize all the crop residues in order to aid in maintaining the supply of organic matter. When this is done, all the farm manure produced is carefully stored and applied to the soil and leguminous crops are utilized as green manures then the organic matter content of the soils may be kept up and satisfactory crop yields insured.

THE USE OF COMMERCIAL FERTILIZERS

There is no large supply of phosphorus in any of the soils in Mills county and quite evidently phosphorus fertilizers will be needed in the very near future, if not at the present time. The total phosphorus content of soils gives merely the supply of that element and does not show how much of it may be in an available form. The low content of phosphorus indicates an insufficient production of available phosphorus. When soils contain a small amount of total phosphorus, therefore, it is quite probable that phosphorus fertilizers will give profitable returns. Even where the supply of phosphorus is not low, however, fertilizers containing the element in an available form may be of value. Hence many of the soils in Mills county may respond to phosphorus fertilization at the present time. The greenhouse experiments and field tests which have been described earlier in this report give indications that the use of phosphorus fertilizers may be very desirable on some of the more extensive soils of the county. Many farmers may find it most desirable to test their own soils for phosphorus needs by making an application to a small area. They may also learn in this way which phosphorus fertilizer to employ.

Rock phosphate and acid phosphate are the two phosphorus carriers which are available for use as fertilizers. Rock phosphate is very slowly available in soils and rather large applications must be made. Acid phosphate contains the element in an available form, but it is more expensive. Smaller applications, however, are made. Both of these materials are being tested in the field experiments which are being carried out in this and adjacent counties and it may be possible later to choose which material should be used under individual farm conditions. For the present, however, definite conclusions cannot be drawn, as sufficient data has not yet been accumulated from these experiments.

Hence it is recommended that farmers test both rock and acid phosphate on small areas on their farm to determine which material gives the most profitable returns. It is relatively simple to carry on such tests on the farm and if definite results are secured on small areas then similar applications may be made to large areas with assurance of profit. Farmers should remember that in comparing these two fertilizers the value of the actual crop increases secured should be set over against the cost of the treatments, if they are to obtain actual economic comparisons. Circular 82 of the Iowa Agricultural Experiment Station gives directions which farmers may follow in carrying out such field tests and it is

hoped that many will aid in this way in solving the phosphorus problem for the state.

THE NITROGEN SUPPLY

In general the soils of the county are not deficient in nitrogen, but the amount present is not sufficient to provide very large crop growth for a long period of years. Nitrogen is removed continually by cropping and by drainage. Some means must be employed, therefore, to keep up the supply of this element. Farm manure returns to the land much of the nitrogen removed by crops. It is, therefore, the most common nitrogenous fertilizer. When carefully stored and applied to the land manure goes far toward keeping up the nitrogen supply. It is generally insufficient, however, to keep up the supply, and manuring should be supplemented by green manuring with legumes if the nitrogen content of the soil is not to decrease.

On the grain farm green manuring is the most important means of keeping up the nitrogen supply. Every rotation should contain a legume and the legume should be well inoculated. It is necessary that all or part of the crop be turned under in the soil if it is to increase the nitrogen content. If the legume is harvested it will not serve as a nitrogenous fertilizer. If it is not inoculated it will be of no more value than a grain crop. But when thoroly inoculated and plowed under in the soil considerable amounts of nitrogen are added and it becomes a nitrogen fertilizer. If the seed only of the legume is harvested then practically all of the nitrogen in the crop is added to the soil and large effects are secured. If the legume is used as a catch crop beneficial effects occur.

Crop residues also aid in keeping up the nitrogen supply in soils. These materials should be most carefully utilized in order that the soils may not become deficient in nitrogen. When crop residues, farm manure and green manures are properly used on the farm the nitrogen supply of the soil may be kept up without the use of commercial nitrogenous fertilizers. The latter may be applied in small amounts as top dressings to stimulate the earlier growth of some crops but their use is not generally recommended in this county at the present time. If they are tested on small areas and show value then they may be applied, but in general it will be found that the leguminous crop as green manure will be much cheaper and quite as satisfactory in keeping up the nitrogen in the soils.

THE SUPPLY OF POTASSIUM

According to earlier analyses the soils of the state are well supplied with potassium and it seems hardly likely that potassium fertilizers will be needed for general farm crops. Only where there is an insufficient production of available potassium would it be desirable to apply commercial potassium fertilizers. If the soil is kept in the best physical condition, well supplied with organic matter and properly drained and aerated there should be a sufficiently rapid production of potassium in an available form to supply crop needs. Tests are being carried out on some experiment fields using potassium fertilizers, and it may therefore, be found that small applications of these materials may be profitable. For the present it can only be recommended that farmers who are interested test the effect of small applications of potassium fertilizers on small areas before they make any extensive applications. These materials cannot be recommended at

present for general use in the county, but if tests show them to be of value then they may be used. Small applications may be quite desirable as top dressings, but should not be used until tests have proven their value.

COMPLETE FERTILIZERS NOT RECOMMENDED

Complete commercial fertilizers cannot be recommended at the present time for general use in this county. The experimental evidence which has been secured by field tests indicate that phosphorus fertilizers give quite as large effects and they are of course much less expensive. Hence the returns secured from the use of phosphorus fertilizers are more economical. Commercial fertilizers must give very much larger crop yields than phosphorus fertilizers if they are to prove as profitable. The results given in this report show very little economic value for the complete fertilizers. There is no objection to the use of commercial brands of fertilizers if they are of value and more profitable than the phosphorus carriers, and farmers may test any commercial fertilizer on their soils and if they secure profitable returns this material may be applied to a larger area with the assurance of profit. It should be emphasized, however, that commercial fertilizers should not be employed until their value has been demonstrated. For the present it seems, for the main soil types in Mills county that phosphorus fertilizers are of quite as much value.

DRAINAGE

The natural drainage system of Mills county is quite adequate to remove the excess moisture from the upland soils of the county. The map given earlier in this report shows how extensively the uplands are covered by streams and intermittent drainageways. The bottomlands of the county are frequently poorly drained, however, and as many of them are heavy in texture and all are rather level in topography, the need of drainage is evidenced in many of these bottomland areas. The Bremer silt loam on the terrace is not adequately drained and would be benefited in many cases by artificial drainage. The Wabash and Lamoure soils on the bottoms are particularly poorly drained. The Cass and Sarpy soils have sandy subsoils and hence are better drained.

Whenever soils are too wet, tiling is very necessary if crop yields are to be satisfactory. Often tiling is the first treatment needed to make soils properly productive. The expense in installing tile may be considerable but the increased crop returns more than offset the outlay. In several areas in Mills county, the straightening and deepening of the stream channels have permitted of better drainage and often tiling would not be of value until the securing of proper outlets is permitted by a deepening of the stream channels. The poorly drained bottoms of the county are subject to overflow and drainage alone will not insure good crop production if the land is not protected from overflow.

THE ROTATION OF CROPS

The continuous growing of any one crop always reduces the fertility of the soil very rapidly. It is necessary, therefore, that some rotation be adopted for all soil conditions if the productivity of the soil is to be maintained. Even if the crop which is grown continuously is a so-called "money" crop, it is a better

paying proposition to follow a rotation for the value of all the crops grown will together be greater than the value of the one crop when calculations are made over a period of years. Farmers should not allow their soils to become unproductive by continuous cropping and too much emphasis cannot be placed on the importance of choosing a good rotation for all farming conditions.

There are many good rotations and no one can be recommended for all conditions. Several satisfactory rotations are in use thruout the state and some of these which are suitable for use in Mills county will be suggested. It should be noted that these rotations may be modified as desirable in order to fit the particular local and farm conditions. In fact almost any rotation may be satisfactory provided it contains a legume and the most profitable crops. The following rotations are suggested for use in this county.

1. SIX-YEAR ROTATION

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

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

2. FOUR OR FIVE-YEAR ROTATION

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

3. FOUR-YEAR ROTATION WITH ALFALFA

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

4. FOUR-YEAR ROTATIONS

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

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

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

5. THREE-YEAR ROTATIONS

First year—Corn
 Second year—Oats or Wheat (with clover seeded in the grain)

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

First year—Corn
 Second year—Oats or wheat (with clover)
 Third year—Clover

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

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

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and the crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the grad-

ual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance but it is less harmful and 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 some areas in Mills county. The Knox silt loam is badly washed in many places and the destructive action is so severe in some areas that the soil can only be utilized satisfactorily for pasture purposes. The Marshall silt loam is also washed and gullied in some areas, and its fertility is consequently seriously reduced. It is important to consider briefly the causes of erosion and the methods which may be employed to prevent or control washing in order that proper means may be employed to protect considerable areas of these soils in this county from serious injury.

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, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In."—The method of "staking in" is better as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed about 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 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 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 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 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 regular repair of washouts or undercuttings may prove very effective.

The modification of this system of “staking in” which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of four to ten feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed 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 placed 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 drainage-ways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and it might be employed to advantage in many other cases.

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

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

LARGE GULLIES

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

BOTTOMLANDS

Erosion frequently occurs in bottomlands and especially where such 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 areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and it often proves very efficient.

Trees.—Erosion is sometimes controlled by rows of such trees as willows which

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

HILLSIDE EROSION

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

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

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

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

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

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

INDIVIDUAL SOIL TYPES IN MILLS COUNTY*

There are fifteen soil types in Mills county and these with the colluvial phase of the Wabash silt loam and the areas of riverwash and meadow, made 18 soil areas. They are grouped in three classes, the loess soils, the terrace soils and the swamp and bottomland soils.**

LOESS SOILS

There are two loess soils in the county belonging in the Marshall and the Knox series. Together they cover 60.3 percent of the total area of the county.

MARSHALL SILT LOAM (9)

The Marshall silt loam is the largest soil type in the county as well as the largest loess type. It covers 58.4 percent of the total area of the county. It occurs on the uplands thruout the county except for the narrow upland area of Knox silt loam in the western part of the county. In fact outside of the Knox, it is the only upland type. Thruout the county the areas of Marshall are cut by the rivers with their adjoining terraces and bottoms, and by the narrow strips of Wabash silt loam and the colluvial phase of the Wabash silt loam along the minor streams and the intermittent drainageways.

The surface soil of the Marshall silt loam is a dark brown silt loam 10 to 14 inches in depth. The subsoil is a light brown silt loam to a depth of 18 to 20 inches, underlaid by a yellowish-brown heavy silt loam or silty clay loam. Thruout much of the type there are faint mottlings of gray, yellow or drab in the lower subsoil. As a whole the type is remarkably uniform especially in the gently undulating areas. In undulating areas the surface soil is usually slightly deeper and is uniformly darker in color. The areas south of Henderson and north of Tabor consist of this somewhat darker soil. The more strongly rolling areas in the western part of the county are a lighter brown in the surface soil. In the forested areas also the soil is somewhat lighter in color. In a few small areas there are narrow bands of glacial till at the base of the slopes. It is not possible to show these areas on the map as they are too small and unimportant. If they were mapped they would be classed as Shelby silt loam. In a few spots the surface soil has been washed away from the steeper slopes and stony areas are found on the tops of crests. These so-called "gall spots" are of little significance in the county. Thruout most of the county, the type is not calcareous but in some areas in the western part, the soil will effervesce with acid. The lower soil layers are generally well supplied with lime. Many tests of the surface soil have shown acidity and hence liming is often needed in the county.

In topography the Marshall silt loam varies from slightly undulating to rolling or hilly. Thruout most of the area, the gently rolling topography prevails. Along the streams and adjacent to the Missouri river, the slopes are often very

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

**"In places the soil names do not agree along the boundaries with those in Pottawattamie county. This is due to changes in correlation resulting from a fuller knowledge of the soils of the state. The soil mapped as Hancock silt loam has been subdivided in this county and parts of it have been classed with the Lamoure and the Bremer soils. The Wabash soils have been subdivided and a large part of their area is now mapped with the Lamoure soils." (From Bureau of Soils Report.)

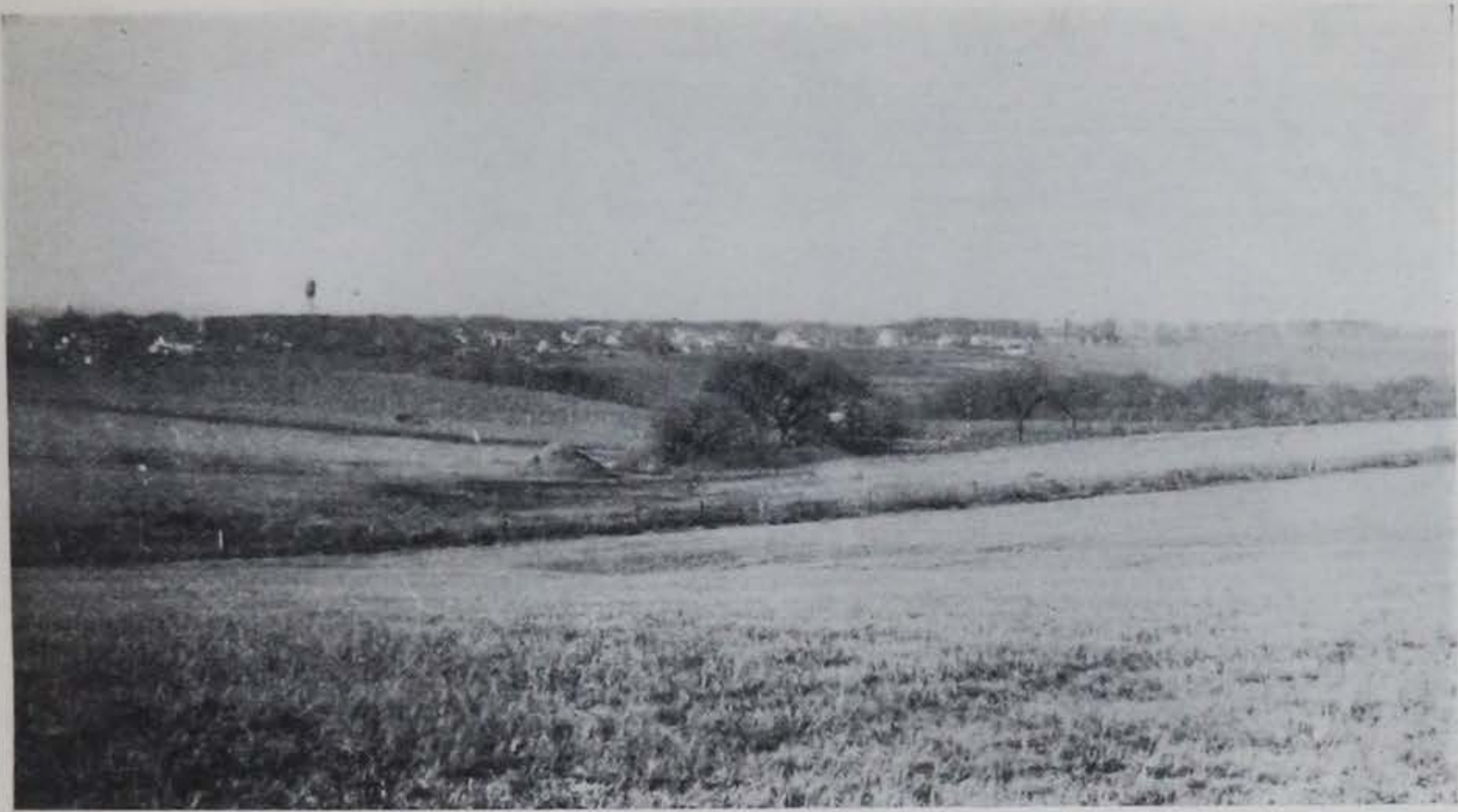


Fig. 5. Malvern located on the gently rolling Marshall silt loam.

steep and erosion has occurred to such an extent that the value of the land has been much reduced. The drainage of the type is everywhere good, as is indicated on the map given earlier in this report.

Most of the type is cultivated but there are a few wooded areas still uncleared. The growth on these areas includes hickory, black walnut, bur oak, red oak, ash, elm, and some basswood. Corn is the chief crop grown and yields of 35 to 50 bushels per acre are secured. Wheat is second in acreage, yielding on the average 13 to 20 bushels per acre. Most of the wheat grown is of the winter varieties. Oats is the third crop in value on the type and yields 40 to 60 bushels per acre. Considerable areas are in hay, clover and timothy mixed being grown most commonly. Some clover is grown alone particularly in the eastern part of the county and yields $1\frac{1}{2}$ to $2\frac{1}{2}$ tons per acre. Some clover is grown for seed. Timothy is also sometimes grown for seed. The yields of clover and timothy mixed amount on the average to $1\frac{1}{2}$ to 2 tons per acre.

Some sweet clover is grown in the county but the acreage is not large. The yields of this crop are very satisfactory and the soil is evidently well suited to the crop. Alfalfa makes up a rather considerable part of the hay crop on the type and it yields from 2 to 4 tons per acre on the average. This crop does well on the Marshall silt loam and it might be grown more extensively with profit. Care in inoculating this crop and in liming the surface soil when seeding, if the area is acid, will aid considerably in insuring a good crop of alfalfa. Some soy beans are grown and the acreage is increasing. They are used for fattening hogs. Some rape is sown with oats for sheep pasturage. Rye is grown to a limited extent for pasture. Some barley is grown as a nurse crop. In the hilly part of the type in the western part of the county, corn and alfalfa are the main crops and they are supplemented by sorghum and navy beans.

The type is well suited to truck crops and fruit and these crops are grown in all parts of the county, largely for home use but to a small extent for mar-

keting also. Tomatoes, cabbage, potatoes, carrots, beans, sweet corn, onions, watermelons and muskmelons do well. Near Glenwood tomatoes, sweet corn and pumpkins are used for canning. Apples, plums, cherries, pears and grapes are grown very successfully but chiefly for home consumption. With more care in the handling of orchards and vineyards, apples and grapes might be grown quite successfully for commercial purposes.

In general the crop yields on the Marshall silt loam are quite satisfactory but in many cases larger crops might be secured if better methods of soil treatment were followed. The type is not well supplied with organic matter and additions of farm manure always give large crop increases. This material should be applied in liberal amounts in order to secure the best crop yields. When farm manure is not available for use, then legumes should be used as green manures in order to build up the soil in organic matter. They will also increase the nitrogen content of the soil and will permit the supply of that constituent to be maintained. Various legumes may be utilized as green manures and the practice is very desirable in many instances, as a supplement to manuring or as a substitute for the use of farm manure.

The type is apt to be acid in the surface soil and when that is true additions of lime are very necessary for the best initial growth of such crops as clover and alfalfa. The phosphorus supply in the soil is rather low and additions of phosphorus fertilizers may prove of large value in many cases. The experiments which have been carried out thus far indicate the profit which may come from the use of phosphorus on this soil. It is not possible yet to say which phosphorus fertilizer should be used and hence it is recommended that farmers test the value of both rock phosphate and acid phosphate on their own soils and thus they may determine which material will give the best results.

In some areas the type is eroded and gullied and it is very necessary in such areas that some means be employed to prevent a serious washing away of the surface soil. From the methods suggested in an earlier section of this report, some method may be chosen which will serve to prevent or control the erosion which may occur. The chief treatment which the type needs to make it more productive is the application of farm manure, the turning under of green manures, the application of lime when the soil is acid and the addition of a phosphorus fertilizer.

KNOX SILT LOAM (11)

The Knox silt loam is a minor type in the county, covering only 1.9 percent of the total area. It occurs only in the hilly section of the county along the Missouri river. It is found on the "bluffs" along the bottomlands which are adjacent to the river. The type is not developed continuously, occurring in narrow strips which are separated from each other by small areas of bottomlands which follow the course of small streams and intermittent drainageways. A few small areas occur east and south of Folsom which are detached from the bluffs proper. The largest areas are found in the northern part of the county and adjacent to the county ditch in the southern part. Rarely do the areas of the type exceed one mile in width.



Fig. 6. Knox silt loam on the bluffs. Wabash silt loam in the foreground.

The surface soil of the Knox silt loam is a light brown to grayish-brown silt loam, extending to a depth of about 8 inches. The subsoil is a yellowish-brown to buff colored silt loam. Both the soil and subsoil are usually highly calcareous. The soil is quite uniform in color and in other characteristics, but in some small areas where there has been an accumulation of organic matter the surface soil is somewhat darker than the typical soil.

The type is strongly rolling to hilly and steep in topography. It is well drained. It is subject to serious erosion and is continually being washed away. The type is unsuited to grain production and is used chiefly as pasture. Good yields of alfalfa are often secured. When the surface topography is not too rough, good yields of corn, oats and wheat may be secured provided the land is well manured. Grapes are successfully grown but there are no commercial vineyards.

Much of this type should undoubtedly be kept in pasture as the topography is too rough for growing cultivated crops. When it is cropped, however, it will respond to applications of farm manure and legumes should be used as green manure to build up the supply of organic matter, in which the soil is deficient. The application of phosphorus fertilizers would also probably prove of value in such cases as the type is low in this constituent. The chief need of the soil is for protection from erosion and care should be taken to prevent the washing away of the surface soil which occurs to such a large extent in many areas.

TERRACE SOILS

There are three terrace soils in the county, classified in the Bremer, Waukesha and Hancock series. Together they cover 4.7 percent of the total area of the county.

BREMER SILT LOAM (88)

The Bremer silt loam is the largest terrace soil in the county, covering 2.4 percent of the total area. It occurs in a number of areas along the Nishnabotna

river and along Silver creek. The largest area is found just east of Malvern. Rather extensive areas also occur both east and west of the Nishnabotna river south of Malvern. It is located on broad areas of terraces separating the bottomlands from the Marshall upland.

The surface soil of the Bremer silt loam is a dark brown or black silt loam, 8 to 12 inches in depth. The subsoil is a dark brown heavy silt loam or silty clay loam which at about 24 inches changes into a mottled gray and rusty brown clay. In depressions and swales, the mottlings and iron stains in the subsoil are more pronounced. It has a level to gently sloping topography and the drainage is poor.

Most of the type is in cultivation and only the poorly drained areas are in pasture. Corn is the most important crop and yields 35 to 80 bushels per acre. Wheat is second in importance and yields 15 to 35 bushels per acre. Oats are grown to some extent and yield 30 to 50 bushels per acre. Excellent yields of hay are generally produced. Alfalfa is grown on the better drained areas and good yields are secured. This crop will not do well on the poorly drained areas. Sudan grass is sometimes grown on the drained land.

This type is naturally a very fertile soil but crop yields are frequently unsatisfactory because of poor drainage. The first treatment generally needed is thoro drainage. This may be accomplished by tiling. The expense involved in tiling may be considerable but the increases in crop yields which are the result of thoro drainage will more than offset the expense. The soil is acid in reaction and applications of lime should be made before such crops as alfalfa are grown. The soil should always be tested and the need of lime ascertained. Small applications of farm manure may be of value on newly drained areas but large amounts of manure should not be used, especially if small grains are to be grown owing to the danger of causing them to lodge. Phosphorus fertilizers will be needed in the future and it is quite possible that applications of acid phosphate would be of value in some cases at the present time. It is suggested that this material be tested on a small area to determine whether it should be applied to larger areas. With proper drainage, the use of lime and possibly the application of phosphorus, this soil may be made very highly productive.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is a minor type in the county, covering 1.9 percent of the total area. It occurs in numerous areas along the West Nishnabotna river and Silver creek and in a few small areas along Wabonsie and Keg creeks. The most extensive areas occur along the West Nishnabotna river in the vicinity of Etta, Hastings, White Cloud and Clark. The type occurs on the terraces separating the bottoms from the Marshall on the uplands.

The surface soil of the Waukesha silt loam is a brown to dark brown silt loam 8 to 14 inches in depth. The subsoil is a brown silt loam or silty clay loam to a depth of 20 to 24 inches below which the material is a light brown heavy silt loam or silty clay loam. In several of the areas, particularly those south of Henderson the subsoil is only slightly heavier than the surface soil in texture. There is frequently considerable colluvial wash on this type from the Marshall on the adjacent upland and the texture of the soil is quite uniformly a silt loam,

thruout the soil section. There is no lime in the soil either in the surface or in the subsoil.

Practically all of the type is in cultivation, the remainder being in pasture. Corn does well and average yields amount to 35 to 75 bushels per acre. Oats are grown to a smaller extent, and yield 25 to 40 bushels per acre. Wheat yields 18 to 30 bushels per acre, and is of some importance on this type. Alfalfa, clover and clover and timothy make up the hay crops grown. Yields of these crops are quite satisfactory, in general.

For alfalfa it is quite important that the soil be tested for acidity and that the proper amount of lime be applied. The use of lime on this type is of value for other crops as well as alfalfa. Red clover will not do as well if the soil is acid and in all rotations, the soil should be tested and limed as necessary if the best growth of all crops is to be secured continuously. The soil will respond to applications of farm manure and this material should be used in liberal amounts. Legumes may often be used as green manures with profitable effects. The application of phosphorus fertilizers may also prove of value and tests of both rock phosphate and acid phosphate on this soil are recommended. By these treatments the crop yields on the Waukesha silt loam may be increased quite considerably. The use of farm manure, green manures, lime and phosphorus will also permit the soil to be kept permanently fertile.

HANCOCK SILT LOAM (23)

The Hancock silt loam is a very minor type in the county, covering only 0.4 percent of the total area. It occurs in the western part of the county in narrow bands on the more gentle slopes at the base of the bluffs, between the Knox silt loam and the bottoms of the Missouri river. The largest individual area is along the northern county line about four miles north of Folsom. The remainder of the type occurs in a narrow strip extending southward beyond Folsom.

The surface soil of the Hancock silt loam is a brown or dark brown silt loam with an average depth of 12 inches. The subsoil is a lighter brown silt loam to silty clay loam. Both the surface and subsoil may be well supplied with lime but usually only the subsoil contains sufficient to effervesce with acid. Small fragments of limestone are sometimes found in the soil, evidently derived from the underlying lime rock. In the vicinity of Burr Oak school, the soil is apparently influenced somewhat by this limestone and resembles the Dodgeville silt loam. The area however is small and of very minor significance. In topography the type is gently sloping and the drainage is quite adequate.

Practically all of the type is cultivated. Corn is the principal crop grown. Alfalfa is grown to some extent and good yields of this crop are secured. All kinds of truck crops do well on the soil. It is ordinarily farmed with the adjacent bottomland soil and is used therefore for a variety of crops.

The Hancock silt loam is naturally a productive soil and the yields of general farm crops secured are usually quite satisfactory. Increases may be obtained however when the soil is properly treated and fertilized. Applications of farm manure give crop increases and this material should be used as far as it is available for use. Applications of phosphorus fertilizers might prove of value and tests of rock phosphate and acid phosphate are very desirable. If the surface

soil is acid, as is true in some cases, then small applications of lime should be made, if alfalfa is to be grown. In general this crop will grow particularly well on this soil because of the high lime content of the subsoil.

SWAMP AND BOTTOMLAND SOILS

There are ten bottomland soils in the county and these with the colluvial phase of the Wabash silt loam and the riverwash and meadow make 13 soil areas. Together these soils cover 35 percent of the total area of the county.

WABASH SILT LOAM (26)

The Wabash silt loam with the colluvial phase of the type which is somewhat larger in area, makes up the largest area of bottomland soil in the county. The typical soil covers 9.2 percent of the total area of the county. It occurs along practically all the major streams of the county. The largest development is along the West Nishnabotna river, and its principal tributaries, Silver, Indian and Farm creeks. It is also found in considerable areas along Keg creek, following it to the point where it enters the flood plain of the Missouri river. There it leaves the channel of the creek and extends southward. Other smaller areas of the type are found along many of the smaller streams of the county and in the Missouri river bottoms.

The surface soil of the Wabash silt loam is a brown silt loam 10 to 18 inches in depth. The subsoil is a dark brown to black silty clay loam. Where the soil occurs in swales and depressions, the surface soil is frequently black in color and the surface soil and subsoil are both somewhat heavier in texture. In some areas the soil is really a silty clay loam, but they are too small to separate and are therefore included with the type. The boundary lines between the type and the colluvial phase and the Waukesha silt loam are often very indistinct and are drawn arbitrarily. There is usually a gradual transition from one soil type to the other.

In topography the Wabash silt loam is fairly level. It is subject to overflow but since the straightening and deepening of the channels of the West Nishnabotna river and Keg creek and the greater part of Silver creek, much of the type has been rendered less subject to overflow. The drainage of most of the type is quite adequate, particularly where the adjacent streams have been deepened and the removal of excess moisture is facilitated.

About 80 percent of the type is either under cultivation or in pasture. On the uncleared areas, the forest growth consists of willow, cottonwood, boxelder, ash and walnut. Corn is the chief crop grown and yields 40 to 75 bushels per acre. The higher yields are secured in more favorable seasons. On the higher lying and better drained areas, oats and wheat are sometimes grown and good yields are secured, in good seasons. Often these crops grow too rank however, and lodge badly. A large part of the type is in grass and much hay is cut. The remainder is pastured. The soil is one of the strongest hay soils in the county.

The chief need of the Wabash silt loam in order to be made more productive is adequate drainage. When this is accomplished and the soil is protected from overflow, good crops are secured. It is important that the type be plowed and



Fig. 7. Pure bred dairy herd near Folsom.

cultivated when in the best physical condition as it will form clods if plowed when too dry or too wet. Small applications of farm manure would aid in making newly drained areas more productive as there will be a stimulation in decomposition processes and a better production of available plant food. Large applications should not be made, and this material should not be applied preceding the small grain crops owing to the danger of causing them to lodge. The soil is acid in reaction and applications of lime would be needed for growing legumes.

WABASH SILT LOAM (COLLUVIAL PHASE) (26a)

The colluvial phase of the Wabash silt loam is quite extensive in area, covering 12.6 percent of the total area of the county. It occurs in numerous areas thruout the county, being found along many of the streams and in practically all the intermittent drainageways. The areas are generally narrow. Two areas larger than the typical, are found in the western part of the county, southwest and south of Glenwood along Pony creek and along the county ditch. The areas frequently separate the upland from the Wabash silt loam on the bottoms, especially where they occur along the larger streams. Sometimes areas of terrace intervene. The majority of the type however follows the intermittent drainage lines.

The surface soil of the colluvial phase of the Wabash silt loam is a brown to dark brown silt loam extending to a depth of 15 to 20 inches. The subsoil is a darker brown silt loam to silty clay loam, to a depth of 3 feet or more. In some areas along the smaller streams there is little difference in color and texture between the surface soil and subsoil. Such areas might have been mapped as the Judson silt loam but they were too small to separate. Some small areas of Wabash silt loam and Wabash silty clay loam, too small to separate out are included with the type. In the large area of the soil, near Pacific Junction, the surface soil is a brown mellow silt loam, to a depth of 12 inches. The underlying



Fig. 8. Knox silt loam bluffs along the Missouri bottoms. Lamoure silty clay loam in foreground.

material is a clay or silty clay. Much of the surface material in this locality is calcareous while the subsoil is not. The other large area south of Glenwood is similar except that the surface soil is deeper often extending to a depth of 3 feet. Again in this area the surface soil is often calcareous. In both these areas, the soil is different from the typical and it is of rather recent formation, being formed by overflow waters from Pony creek carrying large amounts of calcareous soil from the uplands.

In topography the colluvial phase of the Wabash silt loam is level to gently sloping. About 80 percent of it is fairly well drained except in wet seasons. The remainder of the type is too wet for cultivation and is kept in pasture. When cultivated, general farm crops are grown, corn yielding 35 to 75 bushels per acre; oats, 25 to 40 bushels; wheat, 15 to 20 bushels; and hay, 1½ to 2½ tons per acre. Alfalfa and clover are often grown and are valuable crops.

The needs of this soil are very similar to those of the adjoining lands. Drainage is of particular importance and should be carefully secured if the land is to be made productive. The addition of small amounts of farm manure would be of value on newly drained areas. The soil is typically acid in reaction and additions of lime should be made before seeding to alfalfa or clover. The use of phosphorus fertilizers would probably prove of value.

LAMOURE SILTY CLAY LOAM (111)

The Lamoure silty clay loam is the second largest bottom type in the county but it is small in area. It covers only 2.6 percent of the total area of the county. It occurs in several areas along the Missouri river. The largest areas are found south of Pacific Junction and northwest and southwest of Pacific City. A rather extensive area occurs along the Pottawattamie county line and several smaller areas lie in the northern part of the county and two in the southern part.

The surface soil of the Lamoure silty clay loam is a dark grayish-brown to black silty clay loam, 8 to 12 inches in depth. The subsoil is a yellowish-brown

silty clay loam or clay, mottled with gray. The area just south of Pacific Junction is somewhat lighter in color and texture than the typical soil and would have been mapped as Lamoure silt loam if it had been extensive enough. In some of the lower-lying areas, the texture is heavier and approaches the Lamoure clay. Small spots of this type, too small to separate are included with the silty clay loam. In general, the type is very dark in color and it is always well supplied with lime. Generally the surface soil as well as the subsoil will effervesce with acid. In topography the soil is level to gently undulating and it is subject to overflow. The drainage conditions are poor.

The Lamoure silty clay loam is practically all under cultivation or in grass for hay or pasture. Corn is the chief crop grown, yielding 40 to 75 bushels per acre. Wheat yields 18 bushels, oats, 25 to 40 bushels and alfalfa $\frac{1}{2}$ to 1 ton per acre. These crops are all grown successfully when the soil is well drained, and protected from overflow. There is a large acreage in bluegrass which is utilized for pasture. Some clover and timothy are grown for hay but the acreage in alfalfa is slightly larger than that in this crop.

This type is naturally a fertile soil. When well drained excellent crop yields are secured. It is well supplied with organic matter and lime and will not need additions of these materials for some years. Small amounts of farm manure might be of value on newly drained areas, and this fertilizing material will be needed in the future after the soil has been brought under more intensive cultivation and has been well drained for a longer period of time. Additions of phosphorus fertilizers may also be of value in some cases and tests are desirable.

CASS SILT LOAM (106)

The Cass silt loam is a minor type in the county, covering 2.2 percent of the total area. It occurs thruout the Missouri river bottoms in areas of varying size. The larger areas are found to the north, southwest, and south of Pacific Junction. There is also a rather extensive area along the Fremont county line. Several small areas occur in the northwestern corner of the county.

The Cass silt loam has a surface soil which is dark brown in color and a smooth velvety silt loam in texture. It is 10 to 16 inches in depth. The subsoil is a light brown very fine sandy loam becoming more and more sandy with increasing depth, and in some places grading at 28 to 36 inches into a fine sand. The surface soil is usually well supplied with lime and the subsoil is likewise high in lime. In general both surface soil and subsoil will effervesce with acid. The topography of the type is level to gently undulating. The drainage of the soil is adequate, owing to the loose character of the subsoil. The greater part of the type lies above overflow, but in some areas, overflows occur.

The greater part of the Cass silt loam is under cultivation. General farm crops are grown. Corn, wheat, oats, alfalfa, and clover are the principal crops. Corn yields from 40 to 80 bushels per acre and on a number of farms average yields of 65 bushels per acre are secured. Oats yield 35 to 60 bushels per acre; wheat, 15 to 25 bushels; and hay, $1\frac{1}{2}$ to 3 tons. Alfalfa is quite successfully grown and yields from $1\frac{1}{2}$ to 3 tons per acre. Truck crops grow well on the type. Potatoes are grown for home use and heavy yields are secured.



Fig. 9. Gently rolling topography of the Marshall silt loam. In the draws occurs the colluvial phase Wabash silt loam.

This type is generally quite satisfactorily productive and when it is not flooded, good yields are secured. It is well drained and well supplied with lime. The organic matter content is not low but applications of farm manure are very desirable and give good crop increases. If the surface soil is acid in any areas, then lime should be applied before seeding to alfalfa or clover. In general, liming is not necessary. Phosphorus fertilizers might often be of value as the test referred to earlier in this report indicates. Tests of these materials on the individual farms are recommended.

WABASH SILTY CLAY (27)

The Wabash silt clay is a minor type in the county, covering 1.8 percent of the total area. It occurs in three areas in the northern part of the West Nishnabotna river bottoms and in one area in the Missouri river bottoms. The largest area is found southwest of Henderson. The other areas along the West Nishnabotna are small in extent. The area in the southwestern part of the county well back from the Missouri river is quite extensive, occurring as a long narrow area which widens out to a distance of about two miles in one part.

The surface soil of the Wabash silty clay is a dark brown or black silty clay, about 10 inches in depth. The subsoil is a very dark gray heavy silty clay or clay extending to a depth of 3 feet or more. It is heavy and impervious in texture and is locally known as "gumbo." It is sticky and hard to cultivate when too wet and in dry weather large cracks appear. It is flat in topography and is cut by depressions and sloughs. It is very poorly drained and is subject to overflow.

A large part of the type is utilized for pasture and the native grasses furnish excellent pasturage. Large yields of wild hay are secured. Corn is the most extensively grown crop and yields of 40 to 70 bushels per acre are secured. In

wet seasons the corn is apt to be drowned out and millet is then often seeded. On the better drained areas, some wheat is grown.

The type is chiefly in need of drainage and protection from overflow if good crop growth is to be secured. It must be handled carefully, and not plowed when too wet or too dry. Clods formed from improper moisture conditions when the soil is plowed will often remain unpulverized for long periods. Small amounts of farm manure might be of value on newly drained areas, but large amounts should not be used. The soil is acid and if legumes are to be grown, lime should be applied. Phosphorus fertilizers may be of value on some areas and tests of these materials on areas which are brought under cultivation are very desirable.

CASS SILTY CLAY LOAM (51)

The Cass silty clay loam is of minor importance in the county, covering only 1.4 percent of the total area. It occurs in several areas along the Missouri river. The largest area is found just west of Pacific Junction. Smaller areas are found west of Pacific Junction and west and south of Pacific City. Several small areas occur in the northwestern part of the county and in the southern part of the Missouri bottoms.

The surface soil of the Cass silty clay loam is a dark brown silty clay loam, extending to a depth of 8 to 12 inches. The subsoil is a grayish silty clay loam to a depth of 20 inches, where it grades into a yellowish-brown fine sandy loam. The lowest part of the three foot section is often a loose fine sand. Both the soil and the subsoil are highly calcareous. In topography it is level to gently undulating. The drainage is good. It is subject to overflow but lies somewhat higher than the Lamoure silty clay loam with which it is associated and it is rarely flooded. It is lower than the Cass silt loam.

Practically all of the type is cleared and farmed. Corn, oats, wheat, alfalfa and clover are the chief crops grown. Corn yields 40 to 80 bushels per acre; oats, 35 to 55 bushels; wheat, about 25 bushels, and alfalfa from 2 to 4 tons per acre. The largest apple orchard in the county is located on this type in the area west of Pacific Junction. There are about 100 acres in this orchard. The Jonathan and Grimes are the chief varieties of apples grown. The soil is also well suited to the growing of tomatoes, cabbage, potatoes, onions and strawberries.

The yields of crops on this type are very much the same as those secured on the Cass silt loam. The type does not warm up quite as early and hence seeding is sometimes delayed. The addition of farm manure would be of value on this soil and applications of this material should be made. The use of phosphorus fertilizers would also probably prove of value and these materials should be tested on small areas. If truck crops are grown other fertilizers might be used to advantage, choosing those complete commercial brands which are particularly designed for truck crops.

LAMOURE CLAY (166)

The Lamoure clay is a minor type in the county, covering only 1.2 percent of the total area. It occurs in the Missouri river bottoms, in several areas. The largest area is found northwest of Folsom. Several small areas occur in the northwestern part of the county. Only four small areas are found outside of

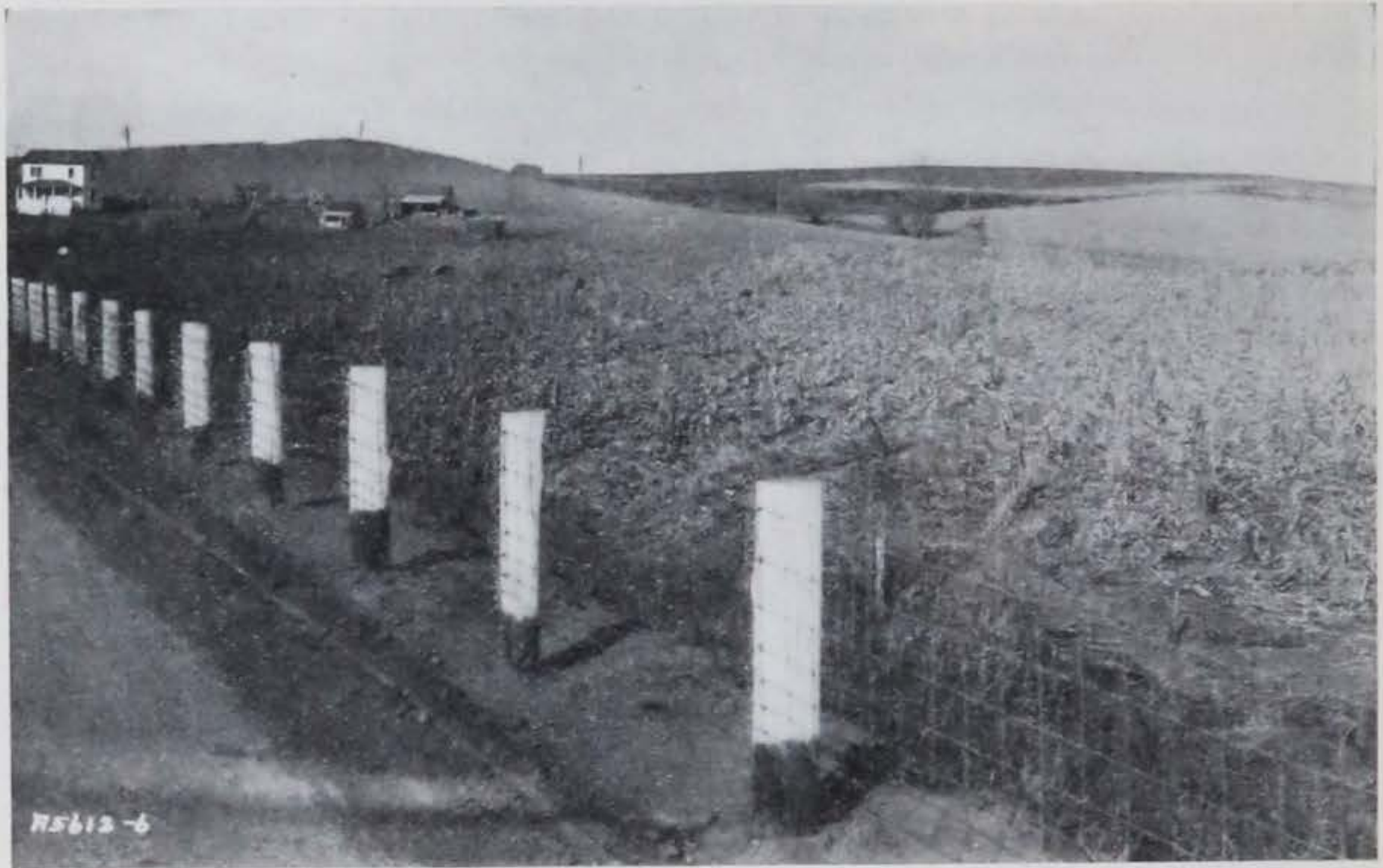


Fig. 10. Marshall silt loam topography.

St. Mary township. The area west of Folsom is 4 to 5 miles long and from one-fourth to one mile in width.

The surface soil of the Lamoure clay is a dark grayish-brown to black clay or silty clay, 6 to 8 inches in depth. The upper subsoil is very similar to the surface soil but slightly darker in color. At 18 to 24 inches it passes into a dark gray or drab clay. Both the soil and subsoil are usually highly calcareous. In general both effervesce with acid. In the area west of Folsom, there are included small knolls and narrow ridges of riverwash which cannot be separated out on the map.

The Lamoure clay is level to flat in topography. It is all subject to overflow except for those areas northwest and northeast of Pacific Junction. Elsewhere the type is in a swampy or semisaturated condition except in dry seasons. The soil is not cultivated. The largest area supports a dense growth of willow and cottonwood and a scant growth of grass. The other areas are covered with a rank growth of sedges and rushes and are used for pasture. Wild grasses are cut for hay on the better drained areas near Pacific Junction. If this soil is to be used for crops, it must be thoroly drained first of all and then protected from overflow. It might then be made to produce good crop yields as it is naturally a rich type.

RIVERWASH (53)

Riverwash occurs in several areas along the Missouri river. The total area of this material amounts to 1.1 percent of the total area of the county. The largest areas are found west of Folsom and west of Pacific City along the river. Smaller areas, usually in narrow strips occur along the river. The greater part of this material consists of fine sand but beds of silt and clay occur at frequent

intervals. In places these areas become part of the stream channel at times of high water. They are formed by the changing stream course and the size of the areas and character of the material is therefore constantly changing. The areas outside the present stream bed are often covered with small willows or cottonwood. Riverwash has no agricultural value.

WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is a minor type in the county, covering 0.9 percent of the total area. It occurs only in the bottoms of the West Nishnabotna river in White Cloud township. There are two areas of the type which are rather extensive one west of the river beginning about one mile west of White Cloud and the other east of the river extending from about one-half mile northwest of Clark to the county line. One very small area is mapped just north of White Cloud.

The surface soil of the Wabash silty clay loam is a dark brown to black silty clay loam 8 to 12 inches in depth. The subsoil is black to very dark gray heavy silty clay loam to a depth of about 20 inches, then grading into a heavy, tenacious silty clay or clay of a similar color. In some areas, where the drainage is poor, the surface soil rests directly on the heavy clay. Small areas of the Wabash silty clay and the Wabash silt loam, too small to separate are included with the type. In topography the soil is level to slightly depressed and the natural drainage is poor. It is subject to overflow but since the river channel has been straightened and deepened overflows are less frequent.

About 95 percent of this type is devoted to pasture, the remainder being utilized for corn. The yields of this crop amount to 35 to 80 bushels per acre, the average being about 50 bushels. Bluegrass, bluestem and slough grass furnish the pasturage. The type at present is better suited to pasture purposes than for cultivated crops. It might be improved for cropping purposes, if it were thoroly drained. It is naturally a fertile soil and should give good crop yields. It is acid and would need lime if legumes were grown. It might respond to phosphorus fertilizers. Farm manure would be of value if used in small amounts on newly drained areas.

CASS CLAY (165)

The Cass clay is a minor type in the county, covering only 0.7 percent of the total area. It occurs in the bottoms of the Missouri river in several areas. The largest areas are found in the extreme southern part of the county along the river. Several smaller areas occur west of Pacific Junction and one small area is located in the northwestern part of the county.

The surface soil of the type is a dark grayish-brown clay, extending to a depth of 8 to 16 inches. The subsoil is a lighter grayish-brown clay to a depth of 20 to 24 inches. Beyond that point it is underlaid by a light grayish-brown fine sand or sticky fine sandy loam. In a few places, recent overflows have covered the soil with a brown silt loam beneath which the typical soil is encountered. Both the surface soil and the subsoil are generally highly calcareous. In topography the type is low and flat. The natural drainage is poor.



Fig. 11. Level bottomland along the Missouri river. Cass fine sandy loam in foreground. Lamoure silty clay loam in background.

The chief crops grown on the soil are corn and wheat. Much of the area in the type is utilized for these crops. In good seasons the yields secured are quite satisfactory but the crops are often ruined by floods. Drainage is the first treatment needed by the soil to make it more productive. It must also be protected from overflow if crops are to be sure. Care is very necessary in handling the soil as it will clod badly if plowed when too wet or too dry. Small applications of farm manure would be of value on newly drained areas but large amounts of this material should not be used. The use of phosphorus fertilizers might also be of value for increasing the yields of crops grown on newly drained areas, or even on areas which have been under cultivation for some time. Tests of phosphorus fertilizers on individual farms are desirable.

MEADOW (20)

There is a small area of meadow in the county, amounting to 0.6 percent of the total area. It occurs in one continuous narrow strip along the course of the Nishnabotna river and along Silver creek where it joins the river. The material ranges from a loose sand to a heavy clay loam. It is extremely variable in character and hence cannot be mapped as a soil type. The areas are cut up by many low ridges and depressions made by former courses of the streams. Practically none of the areas mapped as meadow are cultivated but they are used for pasture.

SARPY FINE SANDY LOAM (102)

The Sarpy fine sandy loam is a minor type in the county, covering 0.6 percent of the total area. It occurs in several small areas along the Missouri river in the bottoms. The largest areas are found in the northwestern corner of the

county, west of Pacific City and around Sharpsburg. Other smaller areas occur in various locations thruout the Missouri river bottoms.

The surface soil of the type is a grayish-brown or brownish-gray fine sandy loam, 8 to 10 inches in depth. The subsoil is a gray fine sand to a very fine sand. In some areas the surface material is a fine sand but these spots are too small to show on the map. In places there are included small amounts of riverwash which cannot be separated out. In some of the depressed areas and narrow swales, there are thin layers of clayey material which may occur at various places thruout the 3 foot section. Both the surface soil and the subsoil are usually well supplied with lime and will effervesce with acid. In topography the type is slightly undulating with occasional low ridges. The drainage is good to excessive. Crops are apt to suffer in dry seasons.

Much of the type is utilized for pasture owing to the danger of overflow. On the areas less frequently flooded, grain and truck crops are grown successfully. Corn is the principal crop and in good seasons, the yields are very satisfactory. Little wheat is grown. Watermelons and muskmelons prove very successful on the type. The soil will respond to liberal applications of farm manure and it would also probably be made more productive by applications of a phosphorus fertilizer. Leguminous crops turned under as green manures would aid in building the soil up in organic matter and permit of better moisture conditions. Protection from overflow would of course be necessary in some of the areas if the soil were to be used for cropping purposes.

CASS FINE SANDY LOAM (130)

The Cass fine sandy loam is a minor type in the county, covering only 0.1 percent of the total area. It occurs in several small areas thruout the Missouri river bottoms, in association with the Cass silt loam. The largest area lies 2½ miles south of Pacific Junction and three of the five other areas are found in St. Mary township.

The surface soil of the type is a dark brown fine sandy loam, 8 to 10 inches in depth. The subsoil is a brown, medium to fine sand. Small areas of the loamy fine sand, too small to separate are included with the type. Both the surface soil and the subsoil is usually well supplied with lime and will effervesce with acid. In topography it is billowy in the larger areas, while the smaller areas occur as low knolls and ridges. It is well drained and in spite of the loose texture is rarely droughty. It lies well above ordinary overflow.

Most of the type is under cultivation and corn is the principal crop grown. It is well adapted to early truck crops and gives good yields of watermelons and muskmelons. Pasture grasses also do well. The soil would be increased in fertility by small additions of farm manure. It might also be made more productive by the addition of a phosphorus fertilizer and tests of the value of rock and acid phosphate are very desirable. If truck crops are grown, then a complete commercial fertilizer, especially made up to favor truck crops probably might be used with profit.

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 cooperation with the Bureau of Soils of the United States Department of Agriculture.

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

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

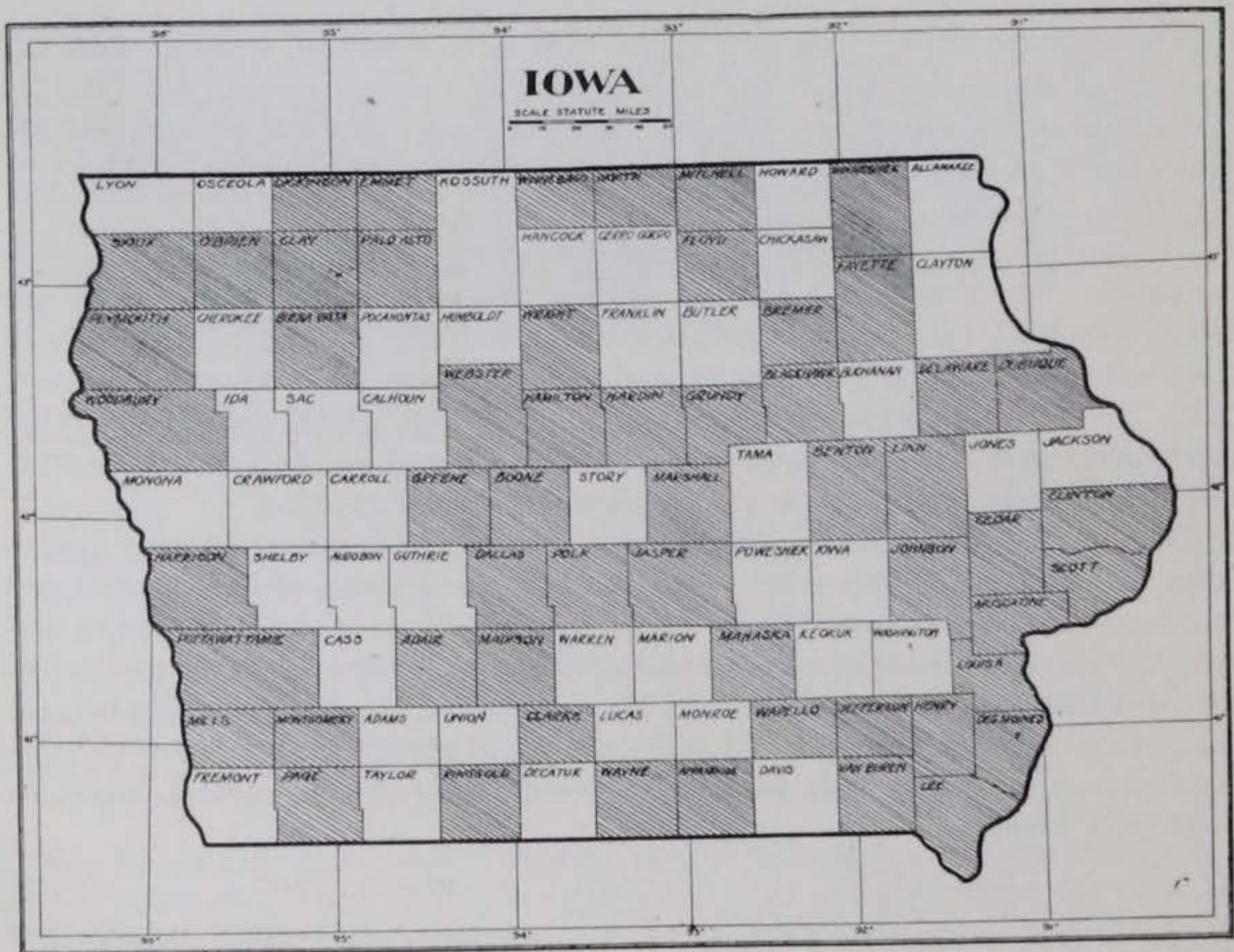


Fig. 12. Map of Iowa showing the counties surveyed.

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.

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

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

PLANT FOOD IN SOILS

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

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

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

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate (Na NO³)), 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
		Nitro- gen	Phos- phorus	Potas- sium	Nitro- gen	Phos- phorus	Potas- sium	
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
Barley, straw ...	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop		48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain ...	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw ...	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop		32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain.....	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop		41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay ...	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay.....	3 T.	120	15	90	19.20	1.80	5.40	16.40

elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

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

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. 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 elements in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

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

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

Of course, if the crops 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-holding power of light soils.

THE ROTATION OF CROPS

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

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.

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

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

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

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

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

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is 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 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 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.

As to the amount of lime needed for acid soils as a general rule sufficient should be applied to neutralize the acidity in the surface soil and then an additional amount of one or two tons per acre.

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. 13.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by the great continental ice sheets. These great masses of ice moved slowly over the land, crashing and grinding the rocks beneath and carrying along with them the 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 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 stone. 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.

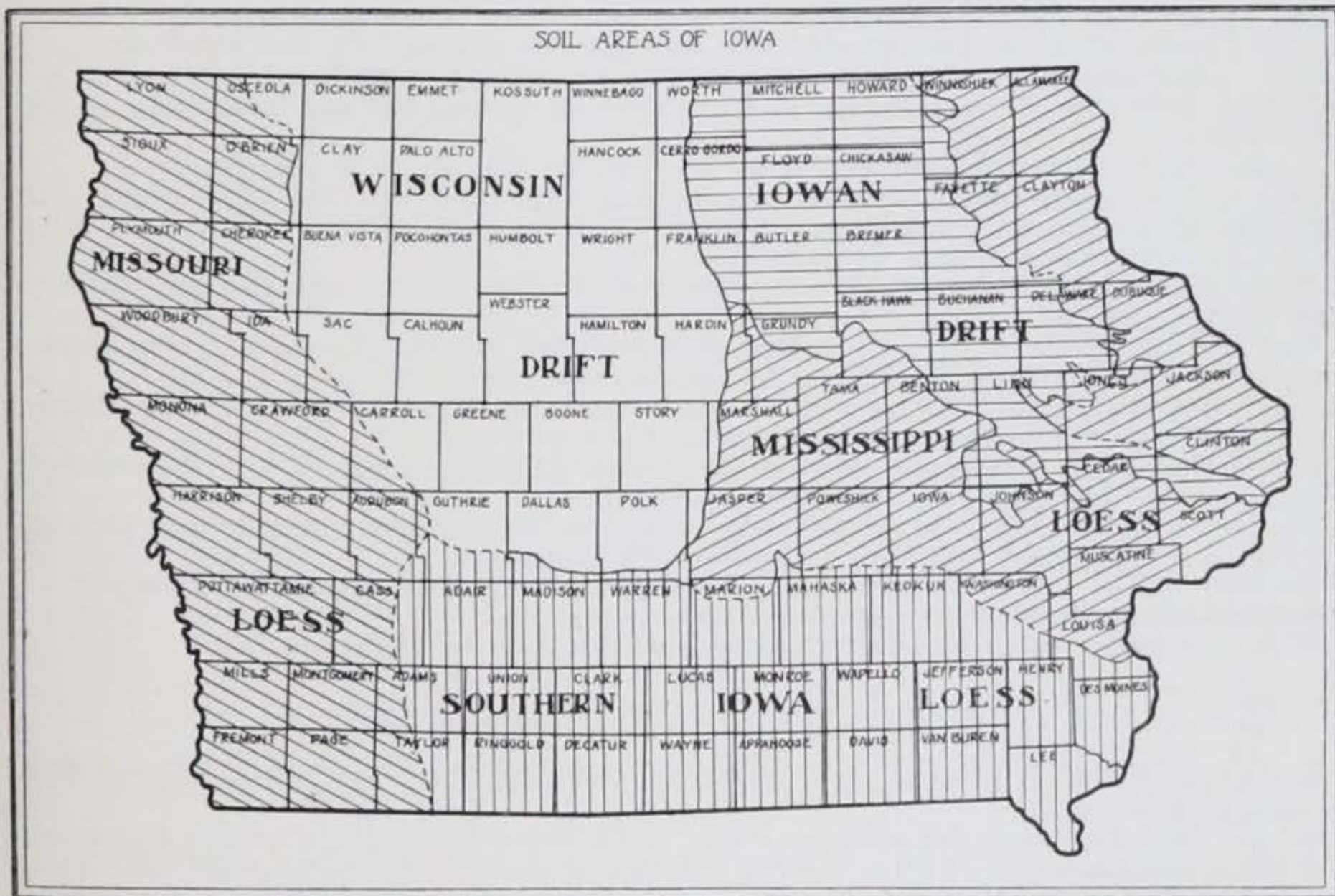


Fig. 13. Map showing principal soil areas in Iowa

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

They are:

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

The common soil constituents may be given as follows:†

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

SOILS GROUPED BY TYPES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Gravels—More than 50 percent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

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

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

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.

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