SOIL SURVEY OF IOWA

MITCHELL COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 11
February, 1919
Ames, Iowa

IOWA AGRICULTURAL EXPERIMENT STATION

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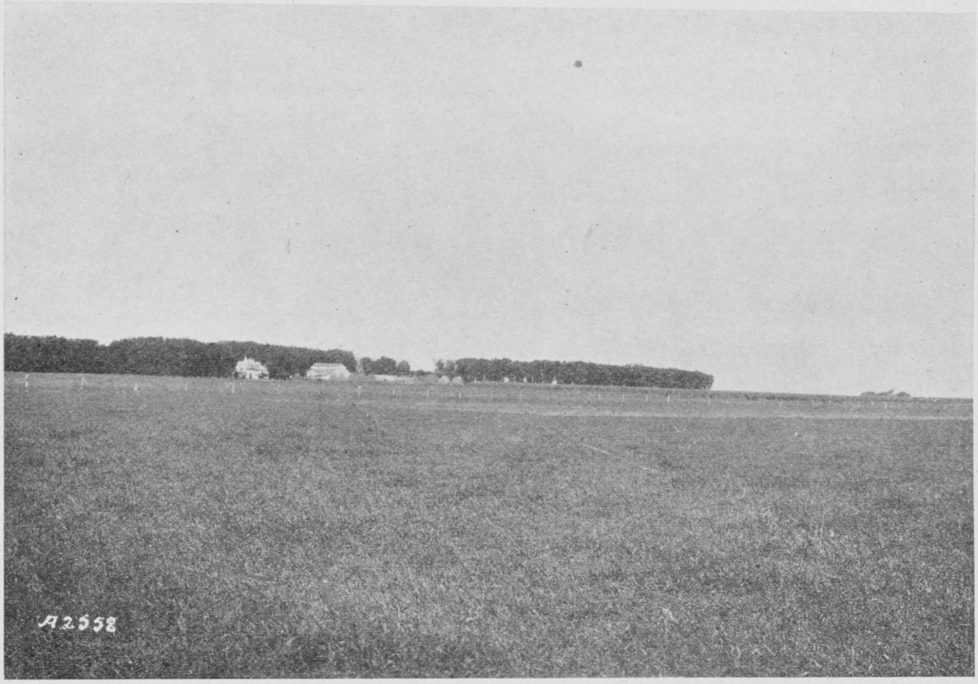
SOIL SURVEY OF IOWA

Report No. 11---MITCHELL COUNTY

By W. H. Stevenson and P. E. Brown, with the assistance of G. E. Corson, Knute Espe and M. E. Olson



A farmstead on Carrington silt loam, east of St. Ansgar

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

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MITCHELL COUNTY SOILS[1]

By W. H. Stevenson and P. E. Brown with the assistance of G. E. Corson, Knute Espe and M. E. Olson

Mitchell county is located in central northern Iowa, bordering the state of Minnesota on the north, Howard county, Iowa on the east, Floyd county on the south, and Cerro Gordo and Worth counties on the west. It is entirely within the Iowan drift soil area and most of the soils are of glacial origin.

The total area of the county amounts to 467 square miles, or 298,880 acres. Of this area 274,713 acres or 92.2 percent is in farm land. The total number of farms is 1,696 and their average size is 161.9 acres.

The following figures taken from the Iowa Yearbook of Agriculture for 1917 show the utilization of the farmland of the county:

Acreage in general farm crops	183,910
Acreage in pasture	65,357
Acreage in gardens	151
Acreage in orchards	272
Acreage in farm buildings, feed lots and public highways	13,472
Acreage in waste land	1,319
Acreage in crops not otherwise listed	1,106

General farming is the type of agriculture which is practiced most extensively in Mitchell county. The livestock industry, especially the raising of hogs, is of considerable importance. The raising and feeding of cattle and sheep are less important branches of the livestock industry. The dairy industry is also followed to some extent. Trucking is practiced in a small area around St. Ansgar, onions, cabbage, potatoes, strawberries and beans being the chief crops. Ginseng and sugar beets are also grown on small areas. Small orchards occur on nearly all farms, apples, cherries, and plums being produced for home consumption.

The area in waste land in the county is rather large and methods of reclamation should be adopted to make such land productive. General methods of treatment cannot be recommended inasmuch as the causes of infertility are so variable, but in the description of individual soil types given later in this report the special treatments required to make waste land productive will be discussed. Advice regarding treatment in special cases will be given by the Soils Section of the Agricultural Experiment Station upon request.

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

Corn is the most important crop from the standpoint of value altho the acreage is slightly smaller than that of oats. Practically all the crop is fed on the farms where it is produced, and but little is sold out of the county.

1 Soil Survey of Mitchell county, Iowa, by W. E. Tharp of the U. S. Dep't of Agriculture and Knute Espe of the Iowa Agricultural Experiment Station.

TABLE I. THE ACREAGE, YIELDS AND VALUE OF CROPS GROWN IN MITCHELL COUNTY [1]

	Acres	Percent of total farm-land in county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crop
Corn	65,000	23.6	27	1,755,000	$ 0.97	$1,702,350
Oats	82,000	29.8	39	3,198,000	0.61	1,950,780
Spring wheat	1,300	0.5	18	23,400	1.94	45,386
Winter wheat	20	0.01	20	400	1.97	788
Barley	2,700	0.9	32	86,400	1.15	99,360
Rye	30	0.01	20	600	1.58	948
Potatoes	2,500	0.9	170	425,000	1.32	561,000
Tame hay	26,200	9.4	1.8	47,200	18.82	888,304
Wild hay	3,200	0.9	1.2	3,800	14.79	56,202
Pasture	65,357	23.7	.....	....	......	....

[1] In Yearbook of Agriculture 1917.

Oats is the second crop of importance in the county and it is grown on a large area. Average yields of 39 bushels per acre are reported, much higher yields being secured in individual cases. Oats are grown mainly as a cash crop and are marketed at local elevators.

Hay is produced on a large area. The crop consists mainly of timothy and clover mixed. Some timothy is grown alone and much seed is produced. Clover is also grown alone on a small area. Wild hay is produced only to a small extent.

Potatoes are an important crop especially in certain sections of the county and average yields of 170 bushels per acre are secured. Barley is grown to a small extent and is used with other grains as feed for stock.

Spring wheat was formerly produced on a considerable area but yields became low and the use of the crop was largely abandoned. At present it is grown only on a comparatively small area. Winter wheat has recently been grown successfully but the acreage in this crop is small.

Alfalfa is grown on a small area. Rye was formerly an important crop but is now produced only to a small extent.

The character and extent of the livestock industry in Mitchell county are shown in the following figures taken from the Iowa Yearbook of Agriculture 1917:

Horses (all ages)	11,566
Mules (all ages)	141
Swine (on farms, January 1, 1918)	36,986
Cattle (cows and heifers kept for milk)	11,876
Cattle (other cattle not kept for milk)	31,348
Cattle (total, all ages)	43,244
Sheep (all ages, on farms)	2,528
Sheep (total pounds wool clipped)	13,155

On most farms the sale of hogs is the largest source of income. The fattening and sale of cattle and sheep also adds much to the income of the county. Dairying is of some importance and creameries are operating profitably at Osage, St. Ansgar and a number of other points.

Land values in Mitchell county advanced rapidly prior to 1914 and most farm land now brings from $100 to $150 per acre. The latter price is the general figure for land of average improvement and location.

The yields of general farm crops and the incomes from average farms in Mitchell county are quite satisfactory. The use of better methods of soil treatment will lead to greater crop yields and hence to larger money returns from the farms.

The soils of the county are quite generally acid in reaction and the application of lime would be of much value, especially for the growth of legumes, such as clover and alfalfa. Many of the soils are low in organic matter and the application of farm manure or green manures would improve the soils and bring about large increases in crop yields. When farm manure is available only to a limited extent, green manures, preferably legumes, should be employed.

The soils of the county are low in phosphorus and the use of phosphorus fertilizers may bring about large crop increases at the present time and in any case will be necessary in the future. Complete commercial fertilizers are not recommended for general use in the county but it is possible they may prove of value in some cases.

Field experiments are now under way to determine the value both of rock phosphate and acid phosphate as well as of commercial fertilizers and in the next few years definite information will be available along these lines. Farmers are urged to test the value of these materials on their own farms and if they are found to be profitable, there is no objection to their use. Only those fertilizing materials which actual tests on the farm have shown to be profitable should be employed.

The drainage of some areas, the proper cultivation of the soil, the rotation of crops and the utilization of all crop residues produced on the farm are other well-known soil treatments which are essential both for increasing crop production and for keeping the soil permanently productive.

THE GEOLOGY OF MITCHELL COUNTY[1]

The underlying rock material in Mitchell county is buried so deeply under the surface deposits of glacial drift that it has practically no influence on the character of the soils. Only in some very small areas near the Cedar river does the rock appear within a few feet of the surface and these areas are of little importance agriculturally. Sometimes the 3-foot soil section rests directly on the rock but usually there is an intermediate layer of clay or sand.

At least twice during the glacial age, the surface of Mitchell county was almost entirely swept over by great glaciers. Upon their retreat, these glaciers left large masses of so-called drift material. The first glacier, known as the Kansan, extended over the entire country but with the exception of a small area, this drift material is buried under the deposit of the later glacier, the Iowan. The soils of Mitchell county are very largely derived from this Iowan drift.

There is a narrow strip of land extending from above Mitchell to Orchard which is covered by loess, but with this exception the soils of the county are drift or terrace or swamp and bottomland soils which are derived from the drift by stream action. It is under this narrow area of loess that the Kansan drift is not covered by the Iowan. Evidently this was an area of higher-lying land which was not covered by the Iowan glaciation and loess was deposited

1 Iowa Geol. Survey. Vol. XIII.

directly on the Kansan till. The loess is a brown, silty material several feet in depth, characteristically thicker on the highest points. It is underlain by coarse sand which in turn rests upon the limestone rocks which form the underlying rock formation of the county.

The typical drift soils of the county are brown to black silt loams or sandy loams, the variations in subsoil material being wide. In places coarse sand or sandy clay is encountered and beds of gravel often occur. The typical subsoil material is a silty clay loam and in some of the flatter areas, a silty clay occurs. The beds of gravel which are sometimes found are of the Kansan glaciation and sand and gravel also occur to a smaller extent in the Iowan drift layer. Bowlders and stones belonging to the Iowan glaciation are sometimes encountered but not to a large extent.

PHYSIOGRAPHY AND DRAINAGE

The surface of Mitchell county is, in general, a gently undulating plain such as is characteristic of the Iowan drift. There are broad areas of upland broken only by the rather deep valleys of the Wapsipinicon, the Cedar and the Little Cedar rivers, and their tributaries. Along these rivers the topography is somewhat rough. This is the characteristic topography of the loess soil area along the Cedar river.

In the northern part of the county there are low, evenly rounded ridges, where the soil is somewhat thinner and more sandy in character. There are areas where the topography is smooth to flat or even depressed and where the need for drainage is pronounced. In general the uplands show the typical undulating topography, with low broad swells and wide, shallow depressions. The terraces along the rivers are not large nor particularly well developed. The larger terraces occur on the eastern side of the Little Cedar and Wapsipinicon rivers. Their surface is usually level and they are from 20 to 30 feet above the flood plains of the streams. The flood plains or bottomlands are comparatively narrow and their topography is level.

The valley of the Cedar river is, on the average, less than 100 feet below the adjacent uplands and less than one-half mile in width. The valley of the Little Cedar river above the town of Little Cedar is very narrow but below, it is one-half to one mile in width. This area includes the terraces which border the flood plains. The valley of the Wapsipinicon is less than one-fourth mile wide and is frequently overflowed.

The drainage of the county is effected by three main streams, the Cedar, the Little Cedar and the Wapsipinicon rivers and their tributaries. The Cedar crosses the western part of the county from northwest to southeast. The Little Cedar and Wapsipinicon rivers are roughly parallel with the Cedar, the former flowing through the eastern central portion of the county and the latter in the extreme east of the county. The large tributaries of each of these streams enter them from the western side. The eastern branches are generally smaller. The most important of the minor streams are Rock creek and Deer creek, tributaries of the Cedar river and Burr Oak and Beaver creeks, tributaries of the Little Cedar river. The accompanying map shows the location of these streams and the general drainage system of the county. The dotted lines indicate the

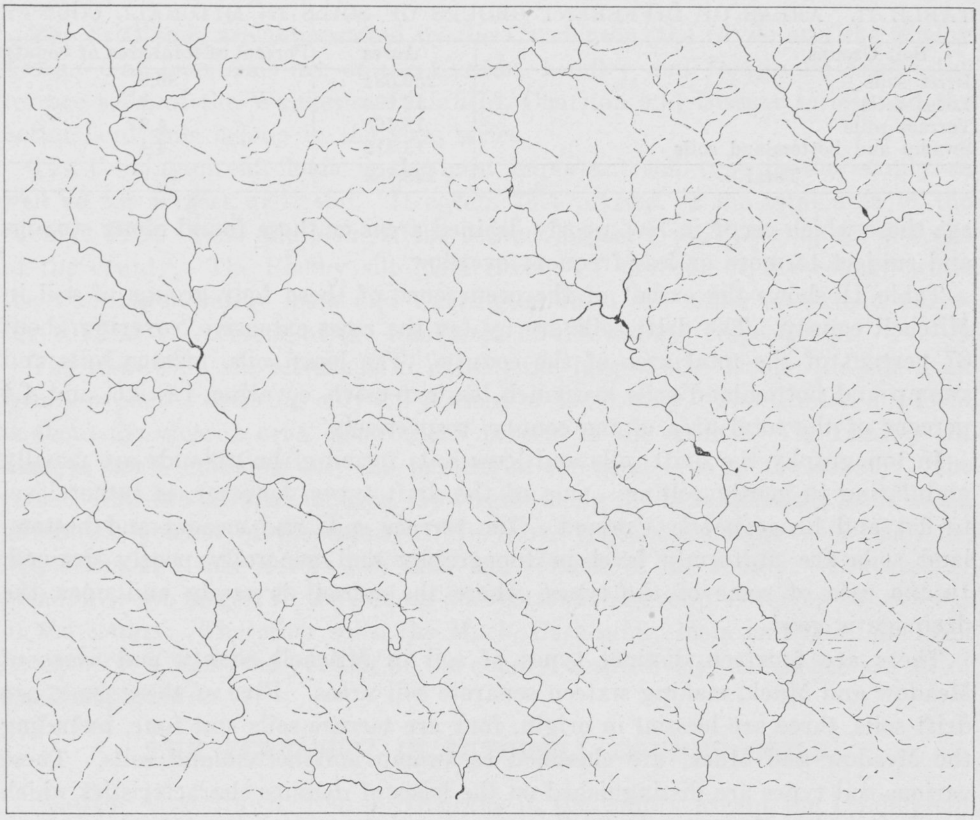


Fig. 1. Natural drainage system of Mitchell county

so-called intermittent drainage channels, which are merely shallow depressions in the upland plain thru which the rain water not absorbed by the soil runs off to the nearest stream.

The natural drainage of the county as a whole is quite adequate and only in the case of a few level areas in the upland and a small acreage of lowland soil, are tile and drainage ditches necessary. In some cases, particularly with the Clyde silt loam, drainage has proved quite profitable.

THE SOILS OF MITCHELL COUNTY

The soils of Mitchell county are grouped into four classes according to their origin and location. These classes are drift soils, loess soils, terrace soils and swamp and bottomland soils. Drift soils are those which are formed from the material deposited by a glacier on its retreat and they usually contain material from various sources and sometimes pebbles and bowlders. Loess soils are deposits of fine, dust-like material made by the wind at some time when climatic conditions were different than at present. Terrace soils are those which were once bottomlands and were raised above overflow by a decrease in volume of the stream or a deepening of the river channels. Swamp and bottomland soils

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

Soil Groups	Acres	Percent of total area of county
Drift soils	259,584	86.9
Loess soils	12,224	4.1
Terrace soils	13,760	4.6
Swamp and bottomland soils	13,312	4.4
Total	298,880	....

are those which occur in low, poorly drained areas or those found along streams and subject to more or less frequent overflow.

Table II shows the extent of the occurrence of these four groups of soil in Mitchell county. The drift soils are by far the most extensive, covering about 87 percent of the total area of the county. The loess soils, terrace soils and swamp and bottomland soils are much less extensive, covering 4.1, 4.6, and 4.4 percent of the total area of the county, respectively.

In topography the drift soils and loess soils forming the uplands are usually undulating to gently rolling. One of the drift types, however, is rather level to flat and hence poorly drained. The terrace soils and swamp and bottomland soils are uniformly level in topography and generally poorly drained. In the case of some of the types, where the subsoil is sandy and open the drainage is good.

There are fourteen distinct types of soil in Mitchell county and areas of Meadow and Muck, making sixteen separate soil areas. Five of these types are drift soils, three are loessial in origin, four are terrace soils and four, including the Meadow and Muck, are classified as swamp and bottomland soils. These various soil types are distinguished on the basis of definite characteristics which are described in the appendix to this report and the names denote certain group characteristics. The areas of the various soil types in the county are shown in table III.

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN MITCHELL COUNTY

Soil No.	Soil Types	Acres	Percent of total area of county
	DRIFT SOILS		
83	Carrington silt loam	222,336	74.4
84	Clyde silt loam	14,208	4.8
93	Shelby silt loam	13,952	4.7
3	Carrington sandy loam	6,016	2.0
1	Carrington loam	3,072	1.0
	LOESS SOILS		
104	Dodgeville silt loam (shallow phase)	5,952	2.0
80	Clinton silt loam	5,568	1.9
32	Lindley silt loam	704	0.2
	TERRACE SOILS		
75	Waukesha silt loam	10,560	3.5
16	Plainfield loam	1,536	0.5
105	Chariton silt loam	896	0.3
88	Bremer silt loam	768	0.3
	SWAMP AND BOTTOMLAND SOILS		
20	Meadow	9,088	3.0
21a	Muck	1,472	0.5
19	Cass sandy loam	1,408	0.5
106	Cass silt loam	1,344	0.4

The drift soils are represented by the Carrington, the Clyde and the Shelby series. The loess soils are of the Clinton, Lindley and Dodgeville series; the terrace soils, of the Waukesha, Plainfield, Chariton and Bremer series, and the bottomland soils belong in the Cass series.

The Carrington silt loam is the most important soil type in the county as well as the largest drift soil. It covers 74.4 percent of the total area of the county. The Clyde silt loam is the second largest type, covering 4.8 percent of the county. The Shelby silt loam covers 4.7 percent of the county while the Carrington sandy loam and Carrington loam are minor in extent, covering 2.0 and 1.0 percent of the total area of the county, respectively.

The loess soils are all small in extent, the largest, the Dodgeville silt loam (shallow phase) covering only 2.0 percent of the county. The Clinton silt loam is about the same in area, covering 1.9 percent of the county. The Lindley silt loam is small, covering only 0.2 percent of the total area of the county. The terrace soils are all small in area, the largest being the Waukesha silt loam which covers 3.5 percent of the county. The other types are smaller even than the Waukesha and each covers less than one percent of the county. The area of Meadow is the largest in the swamp and bottomland group, covering 3.0 percent of the county. The other soils, the Muck, Cass sandy loam and Cass silt loam occupy 0.5, 0.5 and 0.4 percent of the county, respectively, and hence are all of small importance.

THE FERTILITY IN MITCHELL COUNTY SOILS

Samples were drawn from all the soils in the county except the Lindley silt loam, the Bremer silt loam, a minor terrace soil, and the Meadow and Muck

Fig. 2. Carrington silt loam topography looking over a draw of Clyde

which are variable bottomland soils. The more important soil types were sampled in triplicate while with the minor types only one sample was secured. All the samples were taken with care so that they should represent accurately the typical soils and that any variations due to local conditions or special treatments would be eliminated.

The samplings were made at three depths, 0-6⅔ inches, 6⅔-20 inches and 20-40 inches representing the surface soil, subsurface soil and subsoil, respectively.

Analyses were made for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The official methods were employed in the phosphorus, nitrogen and carbon determinations and the Veitch method for the limestone requirement determinations. The results given in the tables are the average of duplicate determinations on all the samples of each type analyzed. Where more than one sample of a type was taken, the results are the average of four or six determinations.

THE SURFACE SOILS

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

The amount of phosphorus in the soils of the county is quite variable, ranging from 800 lbs. per acre up to 2,280 lbs. per acre. The Shelby loam, a drift soil, and the Plainfield loam, a terrace type, contain 800 lbs. of phosphorus and the Carrington sandy loam is only slightly higher, containing 840 pounds per acre. The loess types and the other terrace soils are somewhat higher, containing 1,000 to 1,200 pounds per acre. The bottomland types show 1,400 and 1,600 pounds, respectively. The Carrington silt loam, the largest and most important type in the county, contains 1,200 pounds per acre. The Clyde silt loam and the Carrington loam are the highest in phosphorus, showing 2,200

TABLE IV. PLANT FOOD IN MITCHELL COUNTY, IOWA, SOILS, POUNDS PER ACRE OF TWO MILLION POUNDS OF SURFACE SOIL (0-6⅔″)

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
83	Carrington silt loam	1,200	4,633	54,666	0	7,381
84	Clyde silt loam	2,200	3,760	139,600	0	Basic
93	Shelby silt loam	800	3,340	42,600	0	6,702
3	Carrington sandy loam	840	1,800	19,200	0	9,325
1	Carrington loam	2,280	1,980	63,260	1,140	Basic
	LOESS SOILS					
104	Dodgeville silt loam (shallow phase)	1,000	3,940	51,000	0	4,954
80	Clinton silt loam	1,000	4,060	38,000	0	9,616
	TERRACE SOILS					
75	Waukesha silt loam	1,200	4,100	44,000	0	11,665
16	Plainfield loam	800	1,700	17,600	0	10,907
105	Chariton silt loam	1,000	3,080	32,200	0	9,616
	SWAMP AND BOTTOMLAND SOILS					
19	Cass sandy loam	1,400	5,220	63,000	0	Basic
106	Cass silt loam	1,600	7,020	85,200	0	11,364

and 2,280 pounds per acre, respectively. With the exception of these two latter types, which are both minor in extent, the soils of the county are not very well supplied with phosphorus. There is no relation between phosphorus content and the soil groups but there does seem to be a relationship between the character and color of the soil and the amount of phosphorus which it contains. Thus the sandy loams and lighter colored soils are lower in phosphorus than the heavier types. In general little can be judged regarding the phosphorus in soils from the type and appearance of the soil. An analysis is always necessary.

These analyses as a whole show that phosphorus must be considered in any system of permanent fertility which is adopted for the soils of Mitchell county. Furthermore, it is quite probable that phosphorus fertilizers might prove of value in some cases even now and while definite recommendations cannot be made at the present time, farmers are urged to test the use of such materials on their own soils and determine their value for the particular local conditions.

The field tests which are under way will not be completed for several years and hence no results can yet be given. It is hoped, however, that the results of these field experiments will throw light on the phosphorus problem and together with the experience of farmers will permit of definite recommendations along this line in the near future. A supplementary report will be issued as soon as the field data are available.

The supply of nitrogen in the soils of the county is much more satisfactory than that of phosphorus. There are wide variations in nitrogen content among the soils within the large groups and no definite relations can be shown, except that the bottomland types are somewhat higher in this constituent. The heavier upland soils are better supplied than the sandy types and on the latter soils the addition of nitrogenous fertilizers would probably prove profitable now. In general, nitrogen is probably not the limiting factor for crop growth in many cases in Mitchell county. This does not mean that nitrogen may be disregarded in systems of permanent fertility but merely that if other soil factors are brought up to the best, there will be enough nitrogen for good crop yields. Such materials as crop residues, farm manure and green manures containing nitrogen must, of course, be used regularly on all soils if the nitrogen supply is to be kept up. These materials are also valuable in building up the organic matter content of soils. Inoculated legumes used as green manures are the best means of increasing the nitrogen content of soils and if the soil is in need of nitrogen such crops should be grown and turned under and the soil will be largely benefited.

The organic carbon of the soil is a measure of the amount of organic matter present. There is also a definite relation between the carbon and nitrogen in soils and if there is an abundance of organic matter, the soil is not apt to be low in nitrogen. Thus the amount of organic carbon is closely related to the character and color of the soil just as in the case of the nitrogen. The heavier types and those darker in color are generally richer both in organic carbon and nitrogen. In fact there is such a close relation between color and organic matter that the supply of the latter is usually rather definitely determinable by the depth of color of the soil.

There is no striking relation evident between the organic carbon present in the soils of various soil groups. The bottomland soils, as would be expected, are somewhat richer than the upland types on the average, but the Clyde silt loam, an upland drift soil, is higher in organic carbon than the bottomland types. With the exception of the Carrington sandy loam and the Plainfield loam, which are low, most of the soils in the county are fairly well supplied with organic matter. On all the types organic matter must be supplied from time to time if permanent fertility is to be maintained. Crop residues must all be used, farm manure must be applied in as large amounts as practicable and green manures must be used to supplement or replace farm manure. Farm manure gives increases in crop yields at the present time which are sometimes very large and always profitable. This fact serves to show the value of manure even on soils fairly well supplied with organic matter.

The relation between the nitrogen and carbon is such in some of the types that the need of manure is especially evidenced. The Clinton silt loam, the Waukesha silt loam, the Plainfield loam, the Chariton silt loam, and the Carrington sandy loam are the soils which are particularly in need of manure to increase the production of available plant food or that which is easily taken up by crops. The manure has a threefold value in such cases, by adding plant food, organic matter and bacteria, which are the agencies producing available plant food.

The Carrington loam is the only soil type in the county which shows any inorganic carbon in the surface soil and the amount there is not large. All the soils are evidently in need of lime now or will be in the near future. Three types show a basic reaction by the lime requirement test. In addition to the Carrington loam, the Clyde silt loam and the Cass sandy loam are also basic. These latter types contain no inorganic carbon, however, and hence they will soon need lime. The lime requirements of the other types in the county are variable and the figures given in the table should be considered merely indicative of the lime needs of the soil. Every soil should be tested before lime is applied as different samples of the same type will often vary considerably.

TABLE V. PLANT FOOD IN MITCHELL COUNTY, IOWA, SOILS, POUNDS PER ACRE OF FOUR MILLION POUNDS OF SUBSURFACE SOIL (6⅔" 20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
83	Carrington silt loam	1,866	5,100	36,400	0	14,957
84	Clyde silt loam	3,200	8,940	102,400	0	Basic
93	Shelby silt loam	1,200	2,340	21,600	0	9,324
3	Carrington sandy loam	1,280	2,700	22,400	0	13,404
1	Carrington loam	3,360	8,140	82,920	1,880	Basic
	LOESS SOILS					
104	Dodgeville silt loam (shallow phase)	1,840	3,700	33,440	1,360	Basic
80	Clinton silt loam	1,200	2,980	24,800	0	11,172
	TERRACE SOILS					
75	Waukesha silt loam	1,200	2,860	29,200	0	21,814
16	Plainfield loam	1,200	1,620	13,600	0	15,954
105	Chariton silt loam	1,000	1,860	7,200	0	13,986
	SWAMP AND BOTTOMLAND SOILS					
19	Cass sandy loam	2,800	8,660	115,200	0	Basic
106	Cass silt loam	3,200	9,820	115,600	0	16,738

TABLE VI. PLANT FOOD IN MITCHELL COUNTY, IOWA, SOILS POUNDS PER ACRE OF SIX MILLION POUNDS OF SUBSOIL (20″-40″)

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
83	Carrington silt loam	2,560	3,840	35,800	0	9,456
84	Clyde silt loam	3,000	4,760	48,000	0	Basic
93	Shelby silt loam	1,200	2,120	21,000	0	9,138
3	Carrington sandy loam	1,800	2,480	20,400	0	7,866
1	Carrington loam	3,600	3,200	33,060	23,964	Basic
	LOESS SOILS					
104	Dodgeville silt loam (shallow phase)	1,860	3,680	40,380	40,020	Basic
80	Clinton silt loam	2,100	2,720	27,000	0	13,986
	TERRACE SOILS					
75	Waukesha silt loam	1,800	2,360	16,200	0	6,993
16	Plainfield loam	2,400	1,358	9,600	0	25,353
105	Chariton silt loam	1,200	2,120	6,600	0	8,265
	SWAMP AND BOTTOMLAND SOILS					
19	Cass sandy loam	3,000	6,980	70,800	0	4,361
106	Cass silt loam	3,600	5,720	101,400	0	17,484

All the soils of Mitchell county should be tested for acidity and the lime required as shown by the test should be applied if the best crop growth especially of legumes, is to be secured.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of four million pounds of subsurface soil and six million pounds of subsoil.

The actual plant food content of the lower soil layers has very little influence on the fertility of the soil unless the amount present is considerable. There are no large quantities of any necessary constituents present in the subsurface soils and subsoils in Mitchell county and it is unnecessary to consider the results in detail. The needs of the soil as indicated by the analyses of the surface soils are borne out by the subsurface and subsoil results. Phosphorus will be needed in the future and may prove profitable in some cases even now. Nitrogen and organic matter must likewise be applied to keep the soils fertile.

Only two soil types show any content of lime in the lower soil layers and these are the Carrington loam and the Dodgeville silt loam. The other soil types are either in need of lime at the present time or will be in the future. In the case of the Clyde silt loam the soil is not acid but there is no lime supply and hence applications will be necessary later. Even where lime occurs in the subsoil there is little influence on the reaction of the surface soil. Lime rarely moves upwards in the soil and if the surface soil is acid, lime should be applied regardless of the reaction of the subsoil. It is not advisable to apply sufficient lime to neutralize the acidity below the surface soil but where the lower soil layers are acid as is the case in Mitchell county, it is merely necessary to test the soils at regular intervals and apply lime as needed.

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

Pot No.	Treatment	Weight wheat grain in grams
1	Check	7.65
2	Lime	9.67
3	Lime+Manure	11.95
4	Lime+Acid Phosphate	11.45
5	Lime+Rock Phosphate	10.35
6	Lime+Manure+Acid Phosphate	14.10
7	Lime+Manure+Rock Phosphate	11.45

GREENHOUSE EXPERIMENTS

Two experiments were carried out on the Carrington silt loam, the main soil type in Mitchell county.

The first consisted of treatment with manure, lime, rock phosphate and acid phosphate according to the plan shown in table VII. Lime was applied in sufficient amount to neutralize the acidity and supply two tons additional. Manure was added at the rate of 10 tons per acre, rock phosphate at the rate of 1000 pounds per acre and acid phosphate at the rate of 200 pounds per acre. Wheat was grown in the pots and the yield of grain obtained in grams. The results are given in table VII.

Lime increased the yield of wheat somewhat and manure applied with the lime gave a decided increase in crop. The influence of acid phosphate and rock phosphate used with the lime but without manure was less than that of the manure. When these materials were applied with the manure the rock phosphate had no effect but there was a slight gain for the acid phosphate. Field tests with phosphates might prove them to be profitable at the present time and they certainly will be needed in the future. Manure and lime are of undoubted value and should be used on this soil type.

Fig. 3. First greenhouse experiment on Carrington silt loam. Mature wheat

Fig. 4. Second greenhouse experiment on Carrington silt loam. Clover

The second experiment on the same soil type was arranged somewhat differently. Manure was applied at the rate of 8 tons per acre, lime as before, rock phosphate at the rate of 2,000 lbs. per acre, acid phosphate at the rate of 200 pounds per acre and a complete commercial fertilizer, a standard 2-8-2 brand, at the rate of 300 pounds per acre. Wheat and clover were both grown in this test, the latter crop being seeded when the wheat had been up about a month. The yields of both crops were secured. These yields in grams and the plan of the experiment are shown in table VIII.

The manure brought about a distinct increase in both crops, the effect on the clover being especially evident. Lime increased the wheat slightly but the clover crop was more than doubled. Rock phosphate, acid phosphate and commercial fertilizer had no effect on the clover but small increases were noted in all cases with the wheat. The results secured in this experiment confirm those in the previous test in showing the value of manure on this soil type. That material should be applied in as large quantities as available and practicable and will yield profitable returns. The influence of lime is shown very distinctly on the clover, much greater effects being noted, as would be expected, than with the wheat. The desirability of tests on individual farms to determine the value of phosphorus fertilizers is emphasized. Such materials and perhaps complete commercial fertilizers might prove profitable at the present time. Phosphorus will undoubtedly be needed in the future and only by comparative field tests will it be possible to determine whether acid phosphate or rock phosphate should be employed. For the present it can merely be urged that farmers carry out tests on their own farms and use that material which proves profitable.

TABLE VIII. GREENHOUSE EXPERIMENT, CARRINGTON SILT LOAM, MITCHELL COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	16.93	10.5
2	Manure	19.56	16.0
3	Manure+Lime	20.93	36.5
4	Manure+Lime+Rock Phosphate	22.39	27.0
5	Manure+Lime+Acid Phosphate	23.55	26.0
6	Manure+Lime+Commercial Fertilizer	23.67	36.5

Fig. 5. Wheat in second greenhouse experiment on Carrington silt loam

THE NEEDS OF MITCHELL COUNTY SOILS AS INDICATED BY LABORATORY AND GREENHOUSE TESTS

The field tests in Mitchell county have not been under way long enough to permit of conclusions from the results secured. These results will be published later in a supplementary report. The treatments recommended for the soils of the county are based at present on the laboratory and greenhouse tests as well as on the general experience of farmers. No suggestions are made regarding treatments which have not been shown to be of definite value in the field and are warranted by experience as well as by the results of the laboratory and greenhouse tests.

LIMING

Most of the soils of Mitchell county are at present in need of lime, according to the tests already reported. In fact in only one case is there any lime in the surface soil and all the remaining types if not acid at the present time will quickly become so. It is evident, therefore, that all the soils of the county should be tested for acidity and when acid, lime should be applied. Lime has been found to be a profitable and in many cases, a necessary treatment for acid soils when legumes are to be grown. The influence on other crops is not so evident and none should be expected on small grain crops and corn. Lime should be used in order to insure the best growth of the legume in the rotation and its effect on that crop is sufficient to warrant its application. It is sometimes found that other crops also are benefited by the use of lime, especially when the soil is strongly acid and in some cases the good effect is probably due primarily to the improvement in the physical conditions in the soil. For the latter reason alone the use of lime is necessary if the soil is to be kept permanently fertile, as many plants are not only injured by acid soil conditions but by poor physical conditions, which are responsible for insufficient available plant food production.

Soils are widely different in extent of acidity and the amount of lime needed on any particular soil can be determined only by a test of that soil. There are even variations in acidity among soils of the same type and the average analyses given earlier in this report should be considered merely as indications of the needs of the various soil types. The applications of lime to soils should not be based on such average tests but on tests of the individual soils and in that way excessive or insufficient amounts may be avoided, both of which are undesirable economically.

Farmers may test their own soils for acidity or lime requirements but it will be much more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested, free of charge. In this way a more accurate test may be made and definite recommendations given for the application of lime.

Further information regarding the application of lime, the kind of lime, sources from which lime may be secured and other points connected with the use of lime are given in Bulletin 151 of the Iowa Agricultural Experiment Station.

MANURING

The greenhouse experiments which have already been discussed show very definitely the value of manure on the main soil type in Mitchell county. Farm experience gives abundant confirmation of these results and shows also that the other types in the county would be benefited by the application of manure. Manure is a most profitable fertilizing material for use in Mitchell county. It is probably more valuable economically than other fertilizers and should be used even where commercial materials are to be employed.

Manure is so valuable when applied to the soil that care should always be exerted in storage and application that the greatest effects may be secured. If it is loosely stored or exposed to the weather the losses from manure are very large, in some cases amounting to 75 to 90 percent of its value. The nitrogen which is present in the liquid portion of the manure is largely washed away and when the manure is finally applied to the soil, its value is reduced in proportion to the depletion in plant food. To prevent the losses from manure and a decrease in value on the soil manure should be properly stored. It should be kept under cover, moist and compact or it should be applied to the soil as produced. In either of these cases the manure is used to bring about the best effect on crop production. Thus it will have the greatest influence on the "life" of the soil, adding plant food constituents and delaying the coming of the time when the necessary elements will become deficient. The value of manure is not confined to its content of plant food, however. It has certain effects on the physical condition of soils which are decidedly beneficial and it contains bacteria in enormous numbers. These organisms are the agency which makes plant food available. Hence by the introduction of bacteria, manure increases the production of available plant food so as to bring about the best crop growth.

The average application of manure for most soils amounts to 8 to 10 tons per acre. Larger amounts may be applied to soils with profit but it is not advisable to apply more than 16 to 20 tons per acre for ordinary farm crops and larger returns per ton are secured from applications of 8 to 10 tons. Only when truck crops are grown and it is desired to force the crop is it advisable or economical to use more than 20 tons of manure. On the average farm the production of manure is not great enough to allow for an application of 10 tons once in a four-year rotation, to all the soils on the farm. On grain farms there is only a small production of manure. In such cases green manures must be employed as substitutes for farm manure. Legumes or non-legumes may be used for the purpose but legumes should be chosen whenever feasible. They are quite as satisfactory from the standpoint of organic matter content and effect on the physical conditions in the soil and they have the additional advantage that when well inoculated they are able to utilize the free nitrogen of the atmosphere. Thus they increase the amount of that valuable constituent in the soil. Many legumes are utilized for green manuring purposes and there is such a large variety of legumes that one may be chosen which will fit almost any condition.

Green manuring is a profitable farm practice in many cases when followed to supplement the use of farm manure or as a substitute for manuring. It should not be practiced blindly or carelessly, however, for it may prove unprofitable and in some cases may even become injurious. Advice regarding the use of green manures on individual soils will be furnished by the Soils Section upon request. General information along this line may be secured from Circular 10 of the Iowa Agricultural Experiment Station.

The use of crop residues such as straw and stover is a third means which should be employed to keep up the organic matter content of soils. Such materials should never be burned or otherwise destroyed because when introduced into the soil they improve its physical condition and also return to it considerable plant food. They may be used for feed or bedding on the livestock farm and returned to the soil with the manure. This is undoubtedly the best method of utilization as the straw when mixed with the manure gives a greater beneficial effect on the soil. On the grain farm the crop residues should be used just as carefully for they are the chief means of adding organic matter to the soil. They may add much to the "life" of the soil and they play an important part in keeping the physical condition of the soil satisfactory for the best crop production.

THE USE OF COMMERCIAL FERTILIZERS

The analyses of the soils of Mitchell county did not show the presence of any large amount of phosphorus so it would seem that phosphorus fertilizers might prove profitable at the present time. The greenhouse tests on the

Carrington silt loam, the main soil type in the county, gave indications of value from the use of phosphorus fertilizers. The increases noted in crop yields were not sufficiently large nor consistent to permit of definite recommendations. Further, the results of greenhouse tests should not be considered more than indicative of the needs of a soil. Field tests should be carried out to confirm the greenhouse results before general conclusions are drawn. The field experiments now under way in Mitchell county will not yield results of positive value for several years and for the present definite recommendations regarding the use of phosphorus fertilizers cannot be given. It can be said, however, that such materials may prove of value now and as the soils are low in phosphorus they certainly will be needed in the future. Farmers are urged to test the value of phosphorus fertilizers on their own soils under their particular soil conditions. Both rock phosphate and acid phosphate should be employed to determine the relative merits of the two materials. Acid phosphate is a soluble, readily available phosphorus carrier while rock phosphate is an insoluble, slowly available material, but acid phosphate is more expensive and hence the two materials should be compared to determine which is the more economical. Simple tests may be carried out on any farm with these fertilizers and information of value to the individual farmer thus secured. Aid will also be given toward the solution of the problem for the county in general. Farmers who are interested and wish to test the needs of their own soils will find complete directions for a simple test in Circular 51 of the Iowa Agricultural Experiment Station. Advice and information regarding such tests will also be given by the Soils Section upon request. If a phosphorus fertilizer proves profitable on a small area of a soil, that material may be applied to a large area with assurance of profitable returns and without fear of injury to the soil.

Nitrogen is not low in the soils of the county nor is it so abundant that nitrogenous materials will not be needed to keep the soils permanently fertile. Crop residues and manure return to the soil a part of the nitrogen removed by crops and thus retard the depletion of the soil in that element. However, they do not prevent the gradual decrease in nitrogen in the soil. Commercial nitrogenous fertilizers are not recommended at the present time to add nitrogen to the soil, inasmuch as well-inoculated legumes used as green manures are cheaper and not only supply nitrogen quite as satisfactorily but also add organic matter. Except as top dressing to stimulate the early growth of certain crops, commercial nitrogenous materials are not believed to be profitable on the soils of the county. They may be used if tests prove them to be of value in individual cases.

Potassium is present in such large amounts in all the soils of the state,[1] according to previous analyses, that potassium fertilizers are probably unnecessary at the present time. If the soils of Mitchell county are kept in proper physical condition and reaction for the best crop growth, there should be a sufficient production of available potassium from the store in the soil to keep the crops supplied. Except in small amounts as top dressings, the use of potassium fertilizers cannot be recommended in this county.

[1] Bull., Ia. Agr. Expt. Sta. 150.

Complete commercial fertilizers are probably unnecessary for the best crop production in the county, as potassium is present in sufficient amount for satisfactory crop growth and nitrogen may be more cheaply supplied by the use of inoculated legumes as green manures. Phosphorus fertilizers will probably prove more profitable than the complete materials that contain not only phosphorus but also nitrogen and potassium. It is well in testing such materials to compare them with acid and rock phosphates and thus secure the relative values. The field tests now in progress include a standard 2-8-2 commercial fertilizer and farmers may use such a material in tests which they make on their own soils. If complete fertilizers prove of value according to actual tests, they may be used without fear of injury to the soil.

DRAINAGE

The proper drainage of soils is one of the first requisites for satisfactory crop production. If a soil is too wet the application of fertilizing materials will prove of little value. No other treatment will remedy poor crop yields, if drainage is inadequate. There are four soils in Mitchell county which are in need of drainage to make them more productive. These are the Clyde silt loam, the Bremer silt loam, the Chariton silt loam and the small area of Muck. On some of the other types, there may be small areas where tiling would be of value but in general they are well drained. Tiling is usually all that is necessary to bring about adequate drainage but ditching may be needed also in extreme cases. It is certain that the thoro drainage of soils is worth while in spite of the expense involved and while the latter may be considerable, it will be more than offset by the increased returns from the crops secured.

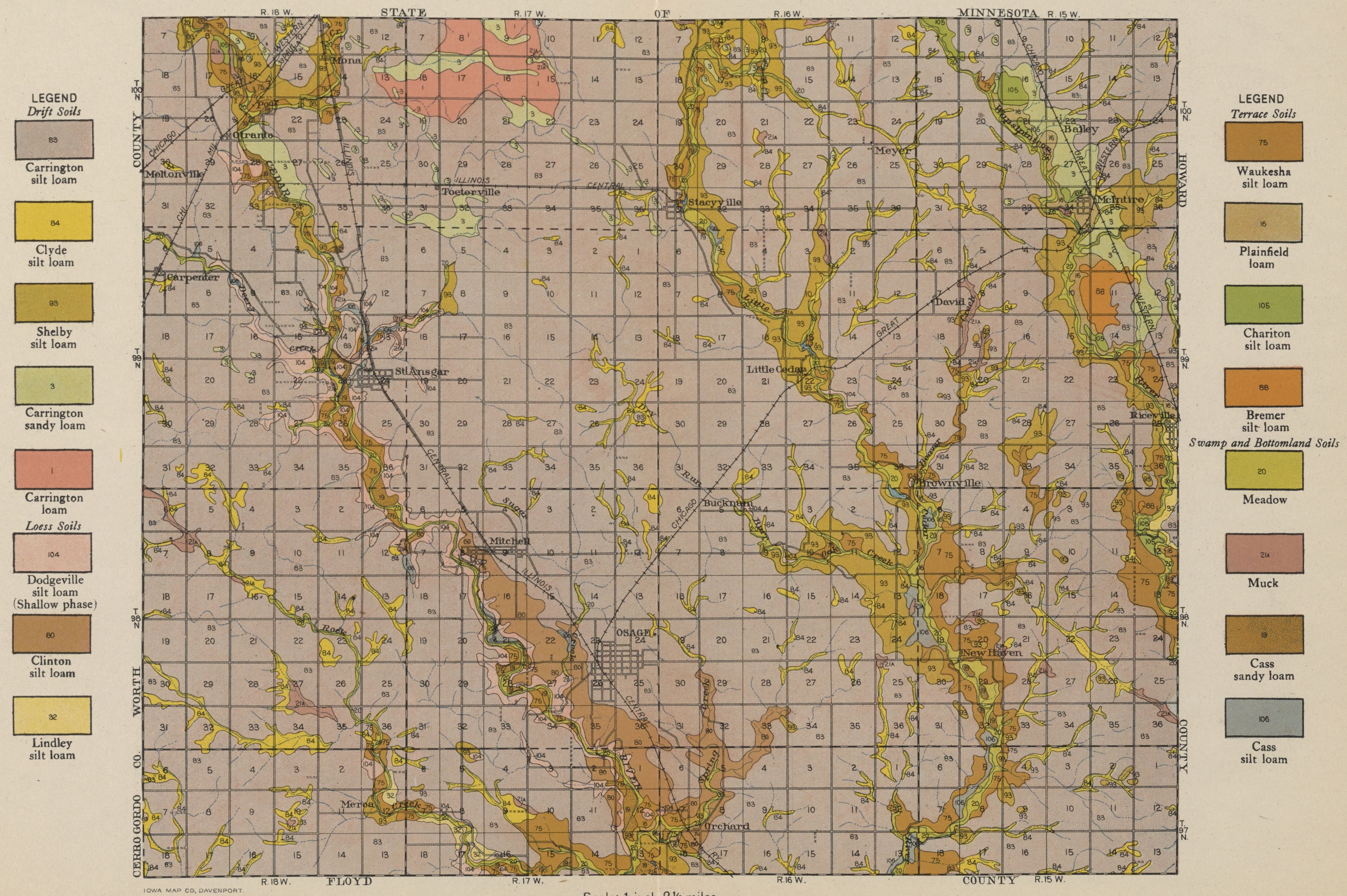
Fig. 6. Looking over Carrington silt loam toward Clinton silt loam, west of Osage

SOIL MAP OF MITCHELL COUNTY

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

Thomas D. Rice, Inspector Northern Division
Soils surveyed by W. E. Tharp, of the U. S. Department of Agriculture, in charge, and Knute Espe, of the Iowa Agricultural Experiment Station

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



Scale: 1 inch-2½ miles

CROP ROTATIONS

The rotation of crops has been found by many experiments and much farm experience to be of more value than the continuous growing of any one crop even tho a so-called "money" crop is involved. For permanent fertility crop rotations are absolutely necessary. Various rotations which have proven quite satisfactory are in use throughout the state and those given below are the most generally employed. Others may be quite as suitable for special conditions and in general it may be said that any rotation may be employed (provided it contains a legume) and will prove more profitable than the continuous growing of one crop.

1. FOUR OR FIVE-YEAR ROTATION

First year: Corn

Second year: Corn.

Third year: Oats (with clover or with clover and timothy).

Fourth year: Clover. (If timothy was seeded with the clover, the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy).

2. FOUR-YEAR ROTATION WITH ALFALFA

First year: Corn.

Second year: Oats.

Third year: Clover.

Fourth year: Wheat.

Fifth year: Alfalfa. (This crop may remain on the land five years. This field should then be used for the four-year rotation outlined above).

3. THREE-YEAR ROTATION

First year: Corn.

Second year: Oats or wheat (with clover seeded in the grain).

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

INDIVIDUAL SOIL TYPES IN MITCHELL COUNTY[1]

DRIFT SOILS

There are five drift soils in Mitchell county belonging to the Carrington, Clyde and Shelby series. Together they cover 86.9 percent of the total area of the county and constitute the most important soils in the county.

CARRINGTON SILT LOAM (83)

The Carrington silt loam is the most extensive drift soil and the largest type in the county. It covers 222,336 acres or 74.4 percent of the total area of the county. It occurs in large individual areas, being the chief type on the uplands. In the wide upland areas between the rivers it is broken only by the small areas of Clyde silt loam which occur in the depressed, intermittent drainage channels, and in the northwestern part of the county by areas of the Carrington loam and sandy loams.

The surface soil to a depth of 10 or 12 inches is a very dark grayish-brown

[1] The description of soil types given in the Bureau of Soils Report have been rather closely followed in this section.

to black silt loam. The subsoil is a rather light yellowish-brown silty clay loam to a depth of 25 or 30 inches. The lower subsoil is generally a brown clay loam to sandy clay and it contains some gravel. Very little sand and gravel occur in the 3-foot section. The underlying drift material is quite variable, ranging from a compact clay to a loose, coarse sand. There are some regional and local variations from the typical soil. Near St. Ansgar on both sides of the river the soil is underlaid by lime rock at a depth of a few feet, a sandy layer usually occurring between the subsoil and the rock. In the northwestern part of the county between the Cedar and Little Cedar rivers much of the type is underlaid by coarse, brown sand. The wide, depressed area in which Toeterville is located has a deep, sandy layer below the subsoil.

East of the area of Clinton silt loam, the Carrington silt loam is silty and rests upon a silty sand. Again the lime rock occurs at rather shallow depths. On the steep slopes the soil sometimes varies from the typical in containing more coarse material and less organic matter. The subsoil is also apt to be coarser in texture.

In topography this soil type is generally strongly undulating to gently rolling. There are small flat and even depressed areas such as the one referred to which occurs around Toeterville. The drainage over the greater part of the type is good. In the flat or depressed areas the drainage is often poor and tiling would be of value. In some cases the depressed areas are characterized by a sandy lower subsoil, in which instances natural drainage is entirely adequate. There are some small areas where a heavy, impervious subsoil prevents thoro drainage even well up on the slopes or at the heads of local waterways. West of the Cedar river the type is only gently undulating and much of it would be benefited by tiling. East of Osage on the upper branches of Spring creek there are also areas where the topography is too flat for a rapid removal of water and drainage is of value.

The Carrington silt loam is well adapted to the growth of general farm crops. Corn yields on the average 50 bushels per acre, higher yields often being secured on the better farms. Oats yield 40 to 60 bushels per acre. Timothy does well but clover does not always prove satisfactory. Wheat yields 20 to 30 bushels per acre in some cases but it is not extensively grown. Truck crops are produced on a small area near St. Ansgar where the soil is silty in character and the underlying material is sandy.

The needs of this soil type to increase crop production and maintain it permanently fertile include the use of tile, whenever necessary to provide adequate drainage, the application of manure in as large amounts as practicable and available, the addition of lime and probably the application of a phosphorus fertilizer. The greenhouse experiments showed considerable effects from the use of lime especially on clover, and where the soil is found to be acid, lime should be applied if the best crops of clover or other legumes are to be secured.

Manure has also been found to bring about large increases in crop yields and its careful storage and application to permit of its full effect on the crop are strongly urged. If manure is not available in sufficient amounts to keep up the organic matter in the soil, inoculated legumes should be turned

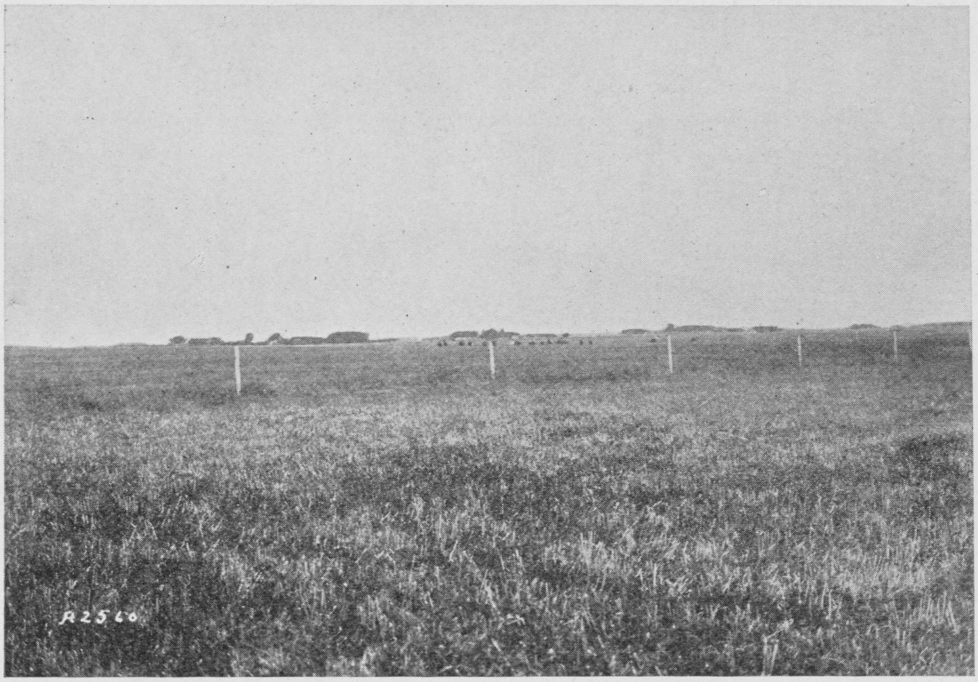


Fig. 7. Carrington silt loam topography, east of St. Ansgar

under as green manures. These latter materials as well as manure should be used in many cases to increase the nitrogen content of the soil. Crop residues should be thoroughly utilized and crop rotations should always be followed. Phosphorus fertilizers may be of value now in many cases on this soil type and tests should be carried out to determine not only the need for phosphorus but also the kind of fertilizer which should be employed. In many cases phosphorus will be needed on this soil in the future. Complete commercial fertilizers are probably unnecessary or at least of less value than the phosphorus fertilizers. They may be used to advantage in some cases, especially where truck crops are being grown. In the latter case brands of fertilizers especially prepared for certain crops should be chosen. Potassium and nitrogenous fertilizers are not necessary at the present time except possibly in the case of truck crops or in small amounts as top dressing for certain crops.

CLYDE SILT LOAM (84)

This soil is the second most extensive soil type in the county. It covers 14,208 acres, or 4.8 percent of the total area of the county. It occurs associated with the Carrington silt loam occupying the lower flat or depressed areas thru which intermittent drainage flows from the surrounding rolling upland. The larger areas are found near the heads of drainageways and are usually shallow, basinlike areas.

The surface soil is a very black silt loam or silty clay loam extending to a depth of about 20 inches. The subsoil is a light-gray or mottled pale-yellow and gray silty clay. It is generally smooth and sticky when wet but becomes granular when dry. In the lower subsoil, sandy clay or comparatively loose sand and gravel are often encountered.

The topography of the type is level to flat or depressed and the drainage is poor. Tile drains have been used in much of the soil and the installations have proven very profitable.

General farm crops are grown and in normal seasons yield fairly well, provided the drainage is adequate. Oats have a tendency to lodge, especially in wet seasons.

The needs of this soil after drainage is accomplished include the use of manure and probably the application of phosphorus fertilizers. These latter materials will, in any case, be needed in the future and lime will be required soon, altho the soil is not acid at present.

SHELBY SILT LOAM (93)

The Shelby silt loam is the third largest type in the county, covering 13,952 acres or 4.7 percent of the total area of the county. It occurs on the rolling areas near the rivers and larger creeks. It is most likely to occur on the steeper slopes and the points of low ridges. The largest areas are found west of the Little Cedar river. Smaller areas are also found near the Cedar river.

The surface soil is a dark grayish-brown to black silt loam usually containing some sand and pebbles. At about 8 inches there is a gradation into a light-brown or yellowish-brown silt loam which is somewhat friable. At about 15 to 20 inches some coarse sand and gravel occur, the amount increasing at the

Fig. 8. Shelby loam near Little Cedar, looking over bottoms

lower depths. At 30 to 40 inches the subsoil is generally a brown or slightly reddish-brown, sandy or gravelly clay.

On the sharper elevations and narrow ridges the surface soil is more sandy in character than the typical soil and contains considerable gravel and some stones. The subsoil at a depth of a few inches, is a brown loam, often heavy and compact but underlaid at less than 3 feet by sand and gravel. In local depressed areas the black soil is deeper and the subsoil is heavier and lighter colored than the typical. There are some small areas where the drainage is poor and this is due to a heavy, light-colored clay or blue clay lower subsoil.

The topography of the soil is rolling and in general the drainage is good. There are some exceptions, as noted above, where artificial drainage is necessary. General farm crops are grown on this soil and the yields, with the exception of corn are very similar to those on the Carrington silt loam. Corn yields are usually lower.

The needs of the soil are for lime, manure or green manures or both, and probably phosphorus fertilizers. The soil is acid and lime is necessary for the growth of legumes. Manure is especially needed to build up the organic matter supply and green manures should also be used.

CARRINGTON SANDY LOAM (3)

The Carrington sandy loam is a minor type in the county covering 6,016 acres or 2.0 percent of the total area of the county. It occurs mainly in the northwestern and northeastern parts of the county along the Cedar and Wapsipinicon rivers. There are small areas in the north central part of the county which occupy "points" or "ridges" rising above the surrounding upland.

The surface soil ranges from a dull-brown sandy loam to a dark-gray or black loam. The subsoil of the lighter areas is usually a brown or yellowish brown rather coarse loam grading, at about 3 feet, into a loose, brown sand. The subsoil of the heavier areas is usually a silty clay loam containing some sand ranging at 30 to 40 inches into a loamy sand. The areas near the state line east of Mona are undulating and the soil is generally a black, friable loam. The areas near Bailey and McIntire consist mainly of a sandy loam. The drainage of the soil is generally good and in some cases it is excessive.

Corn, oats, clover and timothy are the chief crops grown on the soil and the yields are about the same as on the Carrington silt loam.

The soil is in need of lime to remedy acid conditions. Manure should be applied in abundant amounts and green manures should be used to supplement or as a substitute for the manure. Phosphorus fertilizers would probably prove profitable now or if not now, will be needed in the near future. The chief need of the soil, however, is for organic matter.

CARRINGTON LOAM (1)

This is a minor type in Mitchell county covering 3,072 acres or 1.0 percent of the total area of the county. It occurs in one continuous area in the northern part of the county, extending from a point about 6 miles north of St. Ansgar, eastward about 4 miles and north to the edge of the county. It is narrower where it leaves the county, being about 2 miles in width. It is associated with an area of Carrington sandy loam.

The surface soil is a dark-brown to black, mellow loam or silt loam, extending to a depth of about 10 inches. It contains some medium to coarse sand but no gravel. The subsoil is a yellowish-brown silt loam or in some cases are plastic silty clay loam, and extends usually to a depth of 24 inches. With increasing depths, the proportion of sand in the soil increases and the lower subsoil is usually a sandy loam or a coarse loamy sand. The soil underlying the 3-foot section is generally a coarse, sandy material. The more sandy areas of the Carrington loam occur on slight, local elevations while in depressions where the topography is somewhat uneven the soil is heavier and darker-colored. The type is gently rolling in topography and the drainage is good.

The crops grown on the Carrington loam are the same as those grown on the other Carrington soils and the average yields of corn and oats are about the same as on the Carrington silt loam. Clover and timothy do well on this type.

The soil is not acid, so does not need lime. Tests should be made from time to time as all soils tend to become acid rather rapidly when under cultivation. Manure should be applied to the soil and will bring about increases in crop production. Phosphorus fertilizers will be needed in the future but are unnecessary now as the soil is better supplied with phosphorus than the other types.

LOESS SOILS

There are three loess soils in the county belonging to the Dodgeville, Clinton and Lindley series. Together they cover 4.1 percent of the total area of the county and are of much smaller importance than the drift types.

DODGEVILLE SILT LOAM (SHALLOW PHASE) (104)

This soil, the largest of the loess group, covers 5,952 acres or 2.0 percent of the total area of the county. It occurs in narrow areas, mainly along the Cedar river and Rock creek. There are also small areas along some of the other streams. On the Cedar river there are included blufflike areas along the edge of the upland and many limestone cliffs which occur along the stream from Mitchell southward.

The soil is quite variable. It includes areas where lime rock is found at depths less than 3 or 4 feet. A typical section consists of 6 or 8 inches of black silt loam gradually changing with increasing depth into a dull brown silt loam or silty clay loam. At 20 to 30 inches the brown color becomes more pronounced. The lower subsoil is frequently a compact brown or reddish-brown sandy clay carrying rock fragments of various sizes. In some places the lower subsoil is a yellow sticky, somewhat sandy clay or a stiff, brown, granular clay, a few inches in thickness.

The wider areas of the type are deeper and more productive, general farm crops being grown. Much of the type is too steep for agricultural purposes and is used for pasture. When crops are grown, the soil needs lime, manure and probably phosphorus fertilizers to make it more productive.

CLINTON SILT LOAM (80)

The Clinton silt loam is about the same in size as the preceding type, covering 5,568 acres or 1.9 percent of the total area of the county. Only one con-

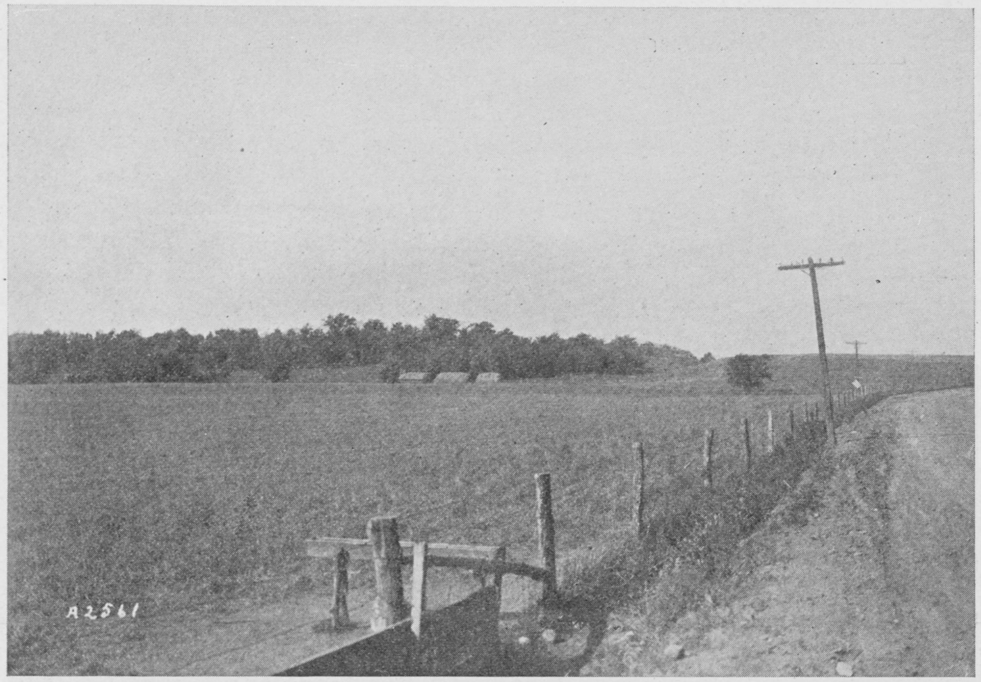


Fig. 9. Dodgeville silt loam west of Osage. Clinton silt loam in background

siderable area of this soil occurs in Mitchell county. It is found in a belt 1 mile in width extending between Mitchell and Orchard on the east side of the Cedar river. A few small areas occur on the west side of the river.

The surface soil is a friable silt loam ranging in color from ashy gray to dark gray. At about 8 inches the color changes to light brown with faint gray mottlings. At lower depths the gray disappears and the material becomes a brown silt loam or in some cases a silty clay loam, rather compact in structure. In the lower part of the 3-foot section, the proportion of sand increases and at a depth of 3 to 4 feet the material is a silty fine sand or a coarser sand.

The topography of the Clinton silt loam is gently rolling. Long, evenly rounded ridges extending in a northwest-southeast direction are characteristic. There are some rounded knolls or mounds. The type is well drained.

The rougher sections of the soil have a scattered growth of trees but most of the areas are in cultivation. General farm crops are grown and good yields are usually secured. Corn averages 40 to 50 bushels per acre, oats about the same as on the Carrington silt loam and red clover, timothy and bluegrass do well but they do not grow as luxuriantly as on the darker colored soils. Some sugar beets and potatoes are grown on the type near Osage.

This soil may be made more productive by proper methods of treatment. It should receive lime when acid and manure or green manures to supply organic matter. Phosphorus fertilizers might prove of value. The chief need of the soil is for manure and this material should be applied in as large amounts as practicable.

Fig. 10. Waukesha silt loam in Mitchell county

LINDLEY SILT LOAM (32)

This is a minor type in the county, covering only 704 acres or 0.2 percent of the area of the county. It occurs in small areas along the Wapsipinicon river near Riceville and along the Rock creek around Meroa.

The surface soil is variable in character. Generally, it is a light-gray silt loam, pasty when wet and loose and floury when dry. The upper subsoil is a compact silt to silty clay loam, ranging in color from gray to light-brown. It is often mottled. The lower subsoil is usually a brown or yellowish-brown sandy clay, containing more or less stony materal. The area near Riceville ranges from light-gray or ashy on the hilltops near the river to dark colored along the county boundary. The higher land is well drained but seepy spots sometimes occur where the under-drainage is poor.

Most of this soil is used for pasture but the darker colored areas are used for the growth of general farm crops. The growth of such crops is usually less than on the Carrington silt loam.

When used for cultivated crops the soil is principally in need of organic matter. Farm manure or green manures should be employed to increase the organic matter content. Lime is needed when the soil is acid and phosphorus fertilizers will probably prove profitable.

TERRACE SOILS

There are four terrace soils in Mitchell county belonging to the Waukesha Plainfield, Chariton and Bremer Series. Together these cover 4.6 percent oi the total area of the county.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the most extensive terrace soil in the county. It covers 10,560 acres or 3.5 percent of the total area of the county. It occurs along the large streams and some of the larger creeks. The largest single areas occur near Orchard along Rock Creek, south of Brownville on the Little Cedar river and north of Riceville on the Wapsipinicon river.

The surface soil is a dark-gray to black silt loam extending to a depth of 10 to 12 inches. It usually contains some sand and gravel. The subsoil is a yellowish-brown or pale yellow silty clay loam which grades, at 20 to 30 inches, into an underlying layer of gravel, composed of pebbles and coarse sand.

In topography, this soil is level or nearly so, except along the base of the uplands where there may be a slight slope. In the areas along the Cedar river, the surfaces are uneven and the soil ranges from a silt loam to a sandy loam. The drainage is generally adequate and only where the subsoil is clayey, does the underdrainage prove insufficient. In general, the sandy or gravelly subsoil insures thoro removal of excess water.

Practically all of this soil is farmed and general farm crops are grown. The yields of crops are quite satisfactory and compare favorably with those secured on the Carrington silt loam.

The needs of the soil to make it more productive include lime, manure and phosphorus fertilizers. Lime is especially needed for the growth of legumes and manure or green manures will prove profitable for all crops. Phosphorus fertilizers may not be of value now but they will be needed in the future.

PLAINFIELD LOAM (16)

This is a minor terrace type covering 1,536 acres or 0.5 percent of the total area of the county. It occurs on the outer or riverward margins of the terraces. In many cases it forms a narrow border along the Waukesha silt loam. These strips include stony, gravelly slopes of the terraces.

The surface soil is a dark-gray to light-brown silty loam usually containing a high percentage of sand and some gravel. At a depth of a few inches this material usually changes to a light-brown loam or silt loam which is friable and open in structure. At about 18 to 20 inches coarse, loose sand and gravel occur and this material extends many feet in depth.

Most of the type is drouthy and a large part of it is used only for pasture. In normal seasons, the deeper areas produce fair crops but dry weather seriously reduces all crops. When cultivated, the soil is in need of lime, manure and phosphorus. It is particularly low in organic matter and phosphorus and should receive liberal application of farm manure or green manures or both and the use of phosphorus fertilizers would probably prove profitable.

CHARITON SILT LOAM (105)

The Chariton silt loam is a minor type covering 896 acres or 0.3 percent of the total area of the county. It occurs in small areas, chiefly along the Wapsipinicon river.

The surface soil is a dark-gray to ashy-gray silt loam, usually containing much fine sand. At a depth of 4 or 5 inches this passes into a light-gray or

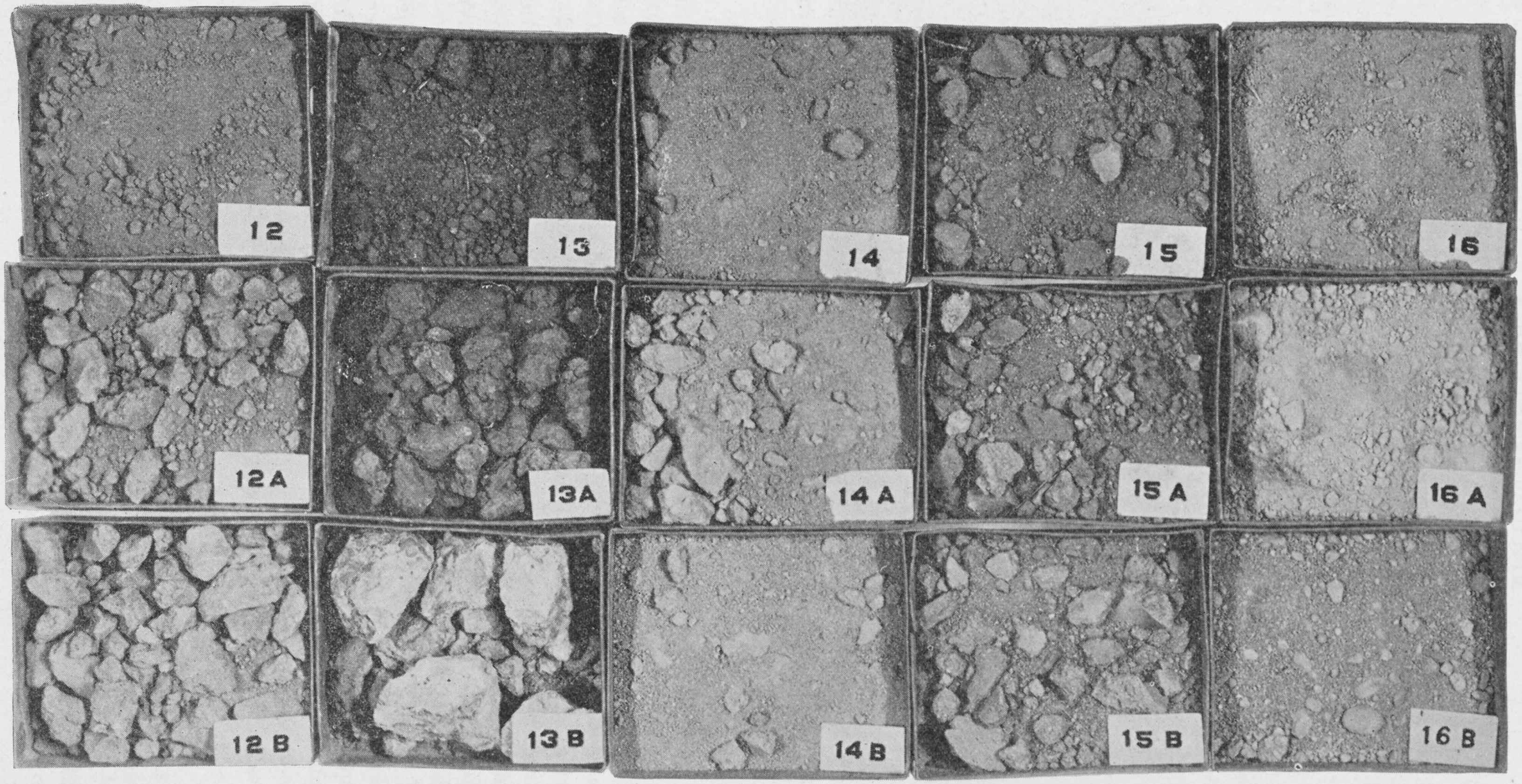


Fig. 11. Surface, subsurface and subsoils on five of the individual soil types of Mitchell county

12. Carrington silt loam
13. Clyde silt loam
14. Carrington sandy loam
15. Dodgeville silt loam, shallow phase
16. Plainfield loam

very pale yellowish-gray silt loam which is friable when dry. At a depth of 18 or 20 inches the material is a compact silty clay containing some sand and small pebbles. This heavy layer continues to a depth of 40 or 50 inches below which there is a gradation to sand and gravel. The small areas of this type south of Riceville vary somewhat from the typical. The surface soil and upper subsoil there consists of a light colored silt loam, overlying rather coarse sand and gravel. At a depth of 3 to 4 feet, a compact clay is found and the drainage is poor.

The topography of the soil is level to flat and the drainage is frequently inadequate, due to the insufficient run-off and to the heavy, impervious subsoil. Tile drainage has been practiced in some places with profit.

Most of the type is used for the production of timothy hay. Red top is usually mixed with the timothy. Clover does not do well. Oats yield satisfactorily on the better drained areas.

The soil needs primarily to be adequately drained. When that is accomplished, lime, manure and phosphorus fertilizers should be used to bring about more satisfactory crop production.

BREMER SILT LOAM (88)

This is a minor type in Mitchell county, covering 768 acres or 0.3 percent of the total area of the county. Small areas of this soil occur in the Wapsipinicon valley, the largest area being south of McIntire.

The surface soil is a black silt loam extending to a depth of 15 or 20 inches. The lower part of this surface material is a rather heavy, granular silty clay. The subsoil is light-drab or very light-yellowish-gray sometimes mottled yellow and brown. At lower depths, the subsoil becomes denser. In places it is a gray, gravelly sticky clay or a bluish-gray clay underlaid by coarse sand and gravel.

The soil is used chiefly for pasture. It is poorly drained owing to the impervious character of the subsoil. With proper drainage, general farm crops could probably be grown quite satisfactorily.

SWAMP AND BOTTOMLAND SOILS

There are four areas of swamp and bottomland soils in Mitchell county, together covering 4.4 percent of the total area of the county. They include Meadow, Muck, the Cass sandy loam and the Cass silt loam.

MEADOW (20)

The area of meadow is the largest among the bottomland soils amounting to 9,088 acres or 3.0 percent of the total area of the county. Meadow is mapped along practically all the streams of the county. The areas along the Cedar river comprise the higher banks of the streams and consist of sandy material which in the wider areas becomes a black sandy loam. Along the Little Cedar river, the soil is a black sandy loam or silt loam. The narrow, uneven flood plain of the Wapsipinicon river is all mapped as Meadow.

Much of this land is in timber and pasture, and bluegrass does well. Only a few small areas are cultivated as the soil is all subject to frequent overflow.

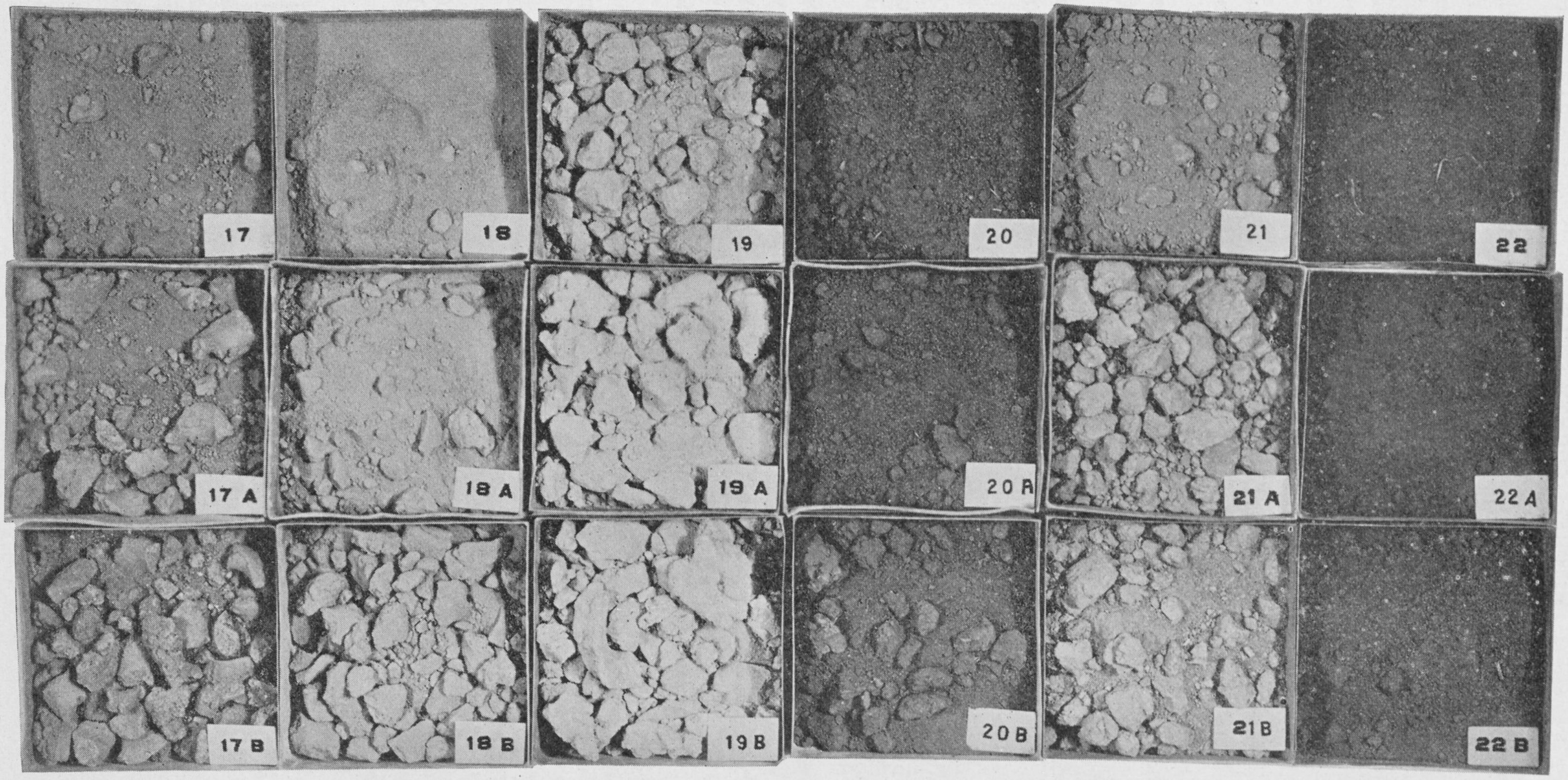


Fig. 12. Surface, subsurface and subsoils on six of the individual soil types of Mitchell county

17. Bremer silt loam
18. Clinton silt loam
19. Chariton silt loam
20. Cass sandy loam
21. Shelby silt loam
22. Cass silt loam

If used for cultivated crops the first need would be protection from overflow.

MUCK (21a)

Muck occurs to only a small extent in the county, covering 1,472 acres or 0.5 percent of the total area of the county. Only a few areas occur which are of sufficient size to be mapped. The largest is about 7 miles west of Osage on a branch of Rock creek. Smaller areas occur on upper Rock creek and in other parts of the county.

The surface material consists of a layer of black, finely divided vegetable remains varying in thickness from a few inches to several feet. It is underlaid by clay or sandy clay. In all cases the depth of the black material is greatest near the center of the area but usually does not exceed 3 or 4 feet.

The areas of Muck in the county are not of great importance but they may be made productive by proper treatment. Corn and small grains do not grow well. Timothy and alsike clover has proved to be the best crop on such land. This crop may be cut for hay or it may be used for pasture. Drainage is the first treatment necessary to bring about satisfactory cropping conditions on Muck. When this is accomplished the soil should be fall plowed and thoroughly cultivated and seeded down. After several years, it will be in shape for the growth of general farm crops. Vegetables are often grown on such land with profit. The treatment of peat soils recommended in Bulletin 157 of the Iowa Agricultural Experiment Station applies to Muck. The latter material is in a condition which permits of the growth of general farm crops much more readily than peat.

CASS SANDY LOAM (19)

The Cass sandy loam is a minor type in Mitchell county, covering 1,408 acres or 0.5 percent of the total area of the county. It occurs in small areas along the larger streams, the largest areas being found along the Cedar river.

The surface soil is a grayish-brown to black coarse textured sandy loam. The subsoil is very similar, being merely a little lighter in color. Below 3 feet a coarse brown sand usually occurs. The narrow areas along the Cedar river are a light sandy loam while the wider areas are usually a black sandy loam or loam.

The soil is all subject to overflow and should be protected by levees if cultivated crops are to be grown. Good yields of corn, potatoes and oats may be secured, where overflow is prevented. The soil should receive applications of farm manure or green manure and may be in need of lime in some cases altho it is not always acid in reaction. Phosphorus fertilizers may prove profitable for use at the present time.

CASS SILT LOAM (106)

This is a minor type, covering 1,344 acres or 0.4 percent of the total area of the county. The largest areas of the soil occur in the Little Cedar river valley. Small areas occur along the Cedar river and along the Wapsipinicon river.

The surface soil is a very dark-brown to black silt loam to loam and extends to a depth of 18 or 20 inches. The subsoil is usually a dull-brown silty material containing more sand than the surface soil. In places the subsoil may be a drab to dark-brown silty clay.

The areas along the Little Cedar river are above the ordinary overflows, as are those areas above Osage on the Cedar river. The drainage of the type is good and good yields of grass, corn and potatoes are secured. The soil should be protected from overflow and with the application of lime as needed, the use of manure and probably of phosphorus fertilizers better crops may be secured and the soil kept permanently fertile.

APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

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

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

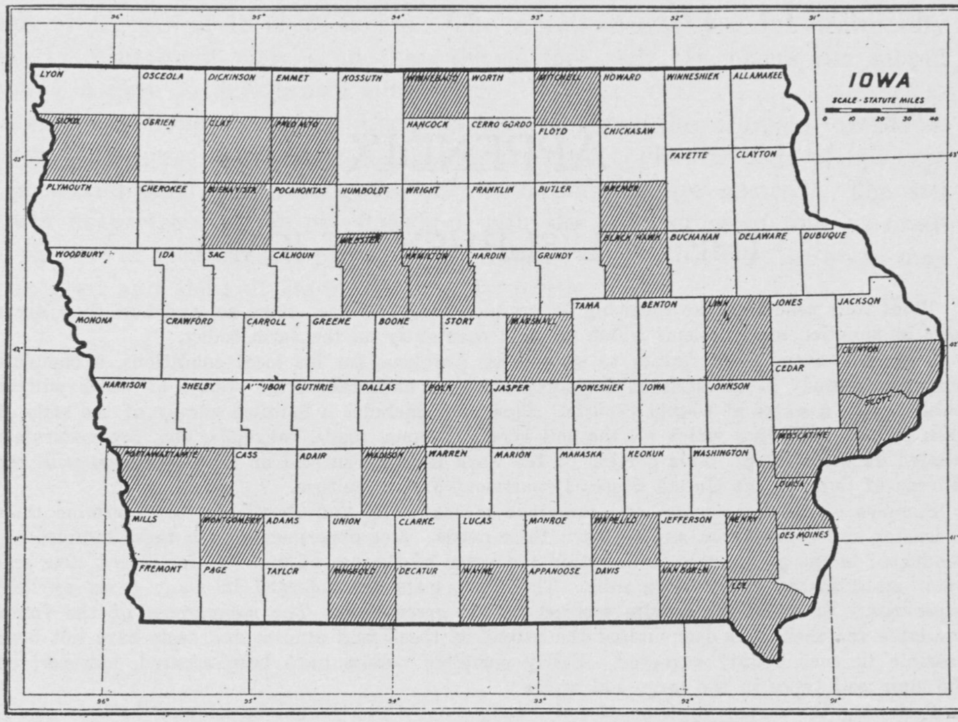


Fig. 13. Map of Iowa showing the counties surveyed

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

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true in 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 in 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 proven 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 ony to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

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

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

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

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

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

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

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished care should always be taken that the soil be 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, although there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

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

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

It is evident from the table that the continuous growing 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

TABLE I. PLANT FOOD IN CROPS AND VALUE

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

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Food Plant
		Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.53	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn crop	......	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	......	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats crop	......	48.5	8	34	7.76	0.96	2.04	14.70
Barley grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley crop	......	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye crop	......	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.52	5.40	17.00
Alfalfa hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

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

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 calculaion is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 per cent of the corn and 35 to 40 per cent of the oats produced in the state is shipped off the farms.

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

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,

* Bulletin 150 Iowa Agricultural Experiment Station.

there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

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

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

CULTIVATION AND DRAINAGE

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

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

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drought 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 drought 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 amount 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 rotations. 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 ekpt 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 large 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 material that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

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

THE USE OF PHOSPHORUS

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

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 all farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

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

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the tests of many representative soils reported in bulletin No. 151 of this Station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfafa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions given in bulletin 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 to two tons per acre.

SOIL AREAS IN IOWA

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

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

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa to-day, 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 soil was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching action in the time which has elapsed since its formation.

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

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

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. The climatic conditions,

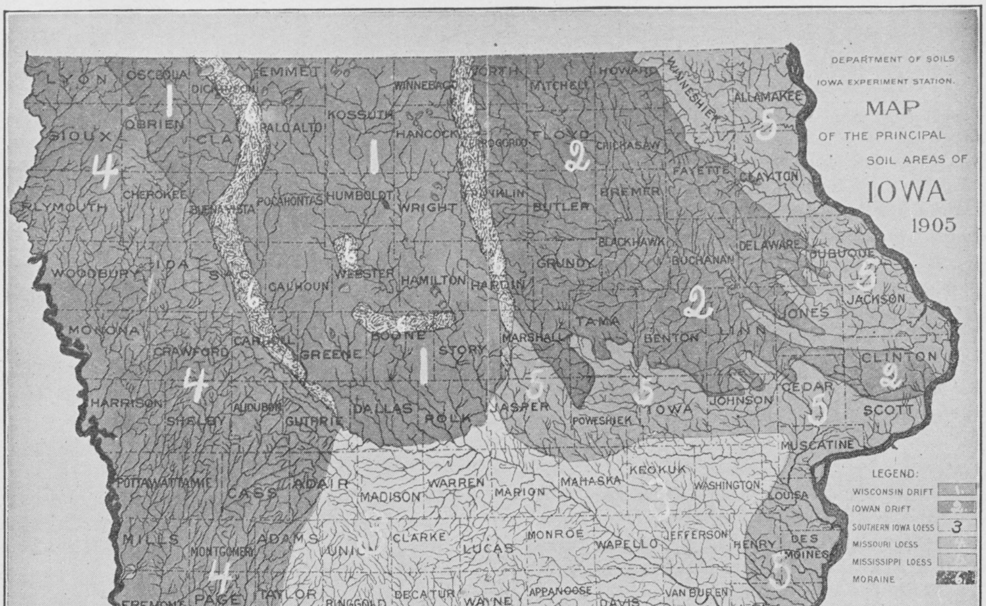


Fig. 10. Map showing the principal soil areas in Iowa

topography, depth and character of the soil, chemical and mechanical composition, and in short all the factors which may affect 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 soil areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

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

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

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

The common soil constituents may be given as follows[1] according to the Bureau of Soils:

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

SOILS GROUPED BY TYPES

The different general groups of soils by types are indicated thus by the Bureau of soils:[2]

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

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

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

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

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

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

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

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

* 25 mm. equals 1 in.

[1] Bur. of Soils Field Book.

[2] 1 C.

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

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

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

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

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

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

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

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

Gravels—More than 50 per cent very coarse sand.

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

METHOD USED IN THE SOIL SURVEY

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

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

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

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

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

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

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

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