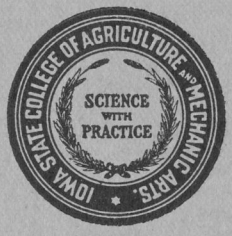
SOIL SURVEY OF IOWA

DICKINSON COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Soils Section



Soil Survey Report No. 37
December, 1924
Ames, Iowa

IOWA AGRICULTURAL EXPERIMENT STATION

PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA

(Those followed by a * are out of print, but are often available in public libraries.)

BULLETINS

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82 The Principal Soil Areas of Iowa.*
95 The Maintenance of Fertility with Special Reference to the Missouri Loess.*
98 Clover Growing on the Loess and Till Soils of Southern Iowa.*
119 The Gumbo Soils of Iowa.
124 A Centrifugal Method for the Determination of Humus.*
150 The Fertility in Iowa Soils.
150 The Fertility in Iowa Soils (Popular Edition).
151 Soil Acidity and the Liming of Iowa Soils.*
151 Soil Acidity and the Liming of Iowa Soils (Abridged).
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161 Maintaining Fertility in the Wisconsin Drift Soil Area of Iowa.*
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7 Bacteria and Soil Fertility.
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1 The Chemical Nature of the Organic Nitrogen in the Soil.*
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9 Amino Acid and Acid Amides as Source of Ammonia in Soils.*
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25 Bacterial Activities and Crop Production.
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35 Effects of Some Manganese Salts on Ammonification and Nitrification.
36 Influence of Some Common Humus-Forming Materials of Narrow and Wide Nitrogen-Carbon Ratio on Bacterial Activities.
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SOIL SURVEY OF IOWA

Report No. 37--DICKINSON COUNTY SOILS

By W. H. Stevenson and P. E. Brown, With the Assistance of L. W. Forman, J. L. Boatman and W. G. Baker

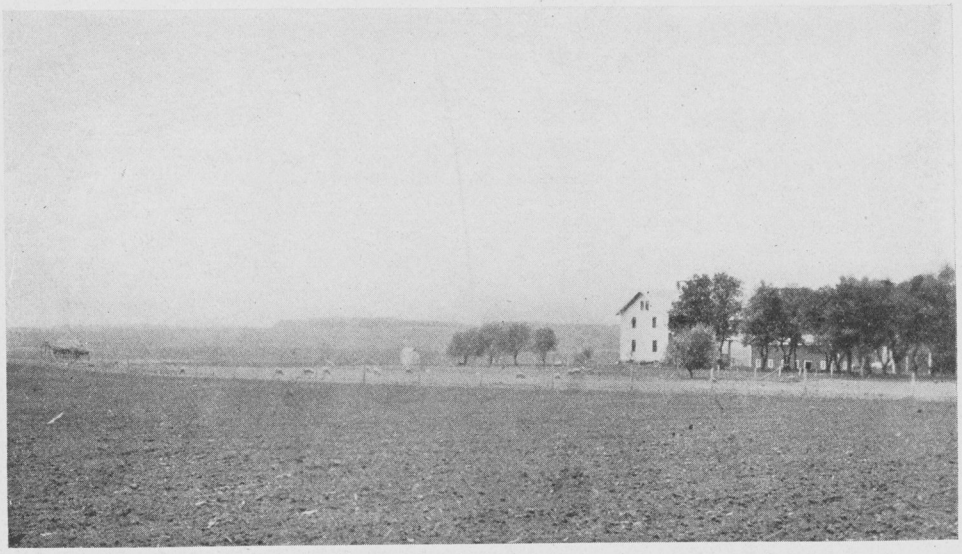

Fig. 1—Farmstead on Carrington Loam in Dickinson county.

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

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DICKINSON COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, With the Assistance of L. W. Forman, J. L. Boatman and W. G. Baker

Dickinson county is located in northwestern Iowa, in the northern tier of counties bordering the state of Minnesota and in the third tier of counties east of the South Dakota state line. Its location is shown on the accompanying sketch map. It lies in the Wisconsin drift soil area and all the soils are of glacial origin.

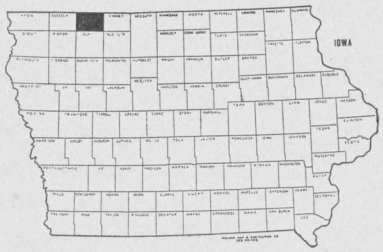


Fig. 2. Location of Dickinson county, Iowa.

The total area of Dickinson county is 240,640 acres. Of this area, 221,038 acres or 91.8 percent is in farm land. The total number of farms is 1,117 and the average size of the farms is 198 acres. In 1922, 368 of the farms were operated by the owners.

The following figures from the Iowa Yearbook of Agriculture for 1922, show the utilization of the farm land of the county:

Acreage in general farm crops	153,080
Acreage in farm buildings, feed lots and public highways	10,566
Acreage in pasture	50,000
Acreage in waste land	2,099
Acreage in crops not otherwise listed	388

THE TYPE OF AGRICULTURE IN DICKINSON COUNTY

General farming is the prevailing type of agriculture in Dickinson county at the present time. Corn, oats and hay are the principal crops.

Many other crops are grown but they are of minor importance. Probably about one-half of the corn crop is marketed, the remainder being fed on the farms. The greater part of the oats produced is used for feed and only a small part of the hay crop is marketed. The livestock industry is well developed in the county but true livestock farming is practiced only to a limited extent. Hog raising is the most extensive livestock industry. The raising and fattening of beef cattle, dairying and the raising of sheep are, however, important industries. Dairying is more commonly practiced than sheep raising but the latter industry, where it is followed, is on a larger scale. The dairy industry receives more attention in the vicinity of the local markets.

There is a rather considerable area of waste land in the county, and much of this land might be reclaimed by the adoption of proper methods of soil treatment. General recommendations along this line cannot be given as the causes of infertility are extremely variable. Frequently drainage is the controlling factor and many areas of unproductive land might be made to produce good crops if the land were thoroly drained. Sometimes erosion prevents the best utilization of land and by following certain methods of handling and cropping such areas, satisfactory yields of crops may be secured. There

*See Soil Survey of Dickinson County, Iowa, by J. A. Elwell of the U. S. Department of Agriculture and J. L. Boatman of the Iowa Agricultural Experiment Station.

are other methods of treatment which are needed in some cases and in a later section of this report suggestions will be offered regarding the best methods of handling individual soils. Where the conditions are very abnormal advice regarding reclamation will be furnished by the Soils Section of the Iowa Agricultural Experiment Station, upon request.

THE CROPS GROWN IN DICKINSON COUNTY

The acreage, yields and value of the various general farm crops grown in Dickinson county are given in table I.

Corn is the most important crop in the county, both in acreage and in value. In 1922, it was grown on more than 31 percent of the farmland of the county. Average yields of this crop amount to 34 bushels per acre. Under favorable seasonal conditions and on the better soil types, the yields are often very much higher. Frequently the corn yields are reduced because of poor drainage conditions. Mixed, home-grown varieties of both yellow and white corn are grown most extensively. Silver King is probably the most popular pure strain. Almost one-half of the corn produced is used for feed on the farms, the remainder of the crop being sold to the local elevators and shipped out of the county, mainly to Chicago. Some of the corn is used for silage. In 1922 there were 129 silos in the county and 11,637 tons of silage were put up. Sometimes soybeans are grown in the corn and included in the silage. Rape is occasionally seeded in the corn and used as forage.

Oats occupy the second largest area in the county and the value of the crop is second to that of corn. In 1922 this crop was grown on more than 25 percent of the total farm land and average yields were estimated at 31 bushels per acre. Again as in the case of corn, the yields of this crop are often very much larger, where the soils are well drained and the seasonal conditions are favorable. Both the early and the late varieties are grown. The principal late variety is the Green Russian and the leading early varieties are Kherson, Iowa 103, Iowa 105 and Early Champion. Mixed home-grown seed is usually sown, except where the crop is grown for seed to be marketed. The greater

TABLE I. AVERAGE YIELDS AND VALUE OF CROPS IN DICKINSON COUNTY, IOWA*

Crop	Acres	Percent of total farm land of the county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	70,000	31.66	34.0	2,380,000	$0.54	$1,285,200
Oats	57,000	25.78	31.0	1,767,000	0.34	600,780
Winter wheat	20	0.009	15.0	300	0.97	291
Spring wheat	210	0.09	12.0	2,520	0.95	2,394
Barley	1,300	0.58	28.0	36,400	0.52	18,928
Rye	80	0.03	15.0	1,200	0.71	852
Potatoes	460	0.20	79.0	36,340	0.62	22,430
Tame hay	14,400	6.51	1.2	17,280	10.40	179,712
Wild hay	9,260	4.18	1.0	9,260	8.50	78,710
Alfalfa	350	0.15	2.2	770	14.80	11,396
Pasture	51,000	23.07	.....	.....	.....	.....

*Iowa Yearbook of Agriculture, 1922.

part of the oats produced is used for feed on the farm, the surplus being sold to the local elevators and shipped to outside markets chiefly Chicago.

Hay is the third crop in importance in the county. The tame hay is the more valuable crop, and it occupies the larger acreage. Average yields of the tame varieties amount to 1.2 tons per acre. The wild hay yields 1.0 ton per acre on the average. The tame hay consists chiefly of clover and timothy mixed. Some timothy is grown alone and occasionaly clover is grown alone. About 700 acres each of timothy and clover are harvested annually for seed. Timothy yields about 4 bushels per acre and clover about 6 bushels. Very little of the hay crop is sold, most of it being fed on the farms. In some cases it is necessary to ship in hay to supplement that grown on the farm.

Potatoes are grown on a relatively small scale, chiefly for home use. Average yields of this crop amount to 79 bushels per acre. Some potatoes are sold on the local markets, but only in a small way.

Some barley is grown in the county and average yields of 28 bushels per acre are secured. It is utilized mainly as a cash crop, altho some of it is fed to young growing stock.

Wheat growing is practiced to a small extent, the spring varieties being grown almost exclusively. The Marquis is the most important variety. Average yields of spring wheat amount to 12 bushels per acre. Wheat is a cash crop and most of it is sold to the flour mills of northwestern Iowa.

Alfalfa is grown to some extent in the county and yields of 2.2 tons per acre are secured. It is a valuable crop and might be grown more extensively. When the soil is well drained, lime is present and the crop is inoculated, good yields are secured. Good seed should always be used and it is important that the seed bed be well prepared. With these precautions, alfalfa becomes a very profitable crop.

Some flax is grown on newly broken sod land, usually on the poorly drained virgin soils. Sweet clover, millet, rye, buckwheat emmer and sorghum are crops of minor importance in the county, being grown on small areas. Sweet corn, garden vegetables and truck crops are grown on the farms for home use. In the vicinity of the lakes, trucking is practiced on a small scale to supply the demands of the summer population.

Apples are grown on most farms but the orchards are not generally well taken care of and the yields are low. The crop is all utilized for home consumption. Peaches, cherries, plums and grapes are grown on some farms. Small fruits such as raspberries, blackberries and strawberries are grown in a small way, chiefly in the vicinity of Milford.

THE LIVESTOCK INDUSTRIES IN DICKINSON COUNTY

The livestock industries of the county include the raising of hogs, the raising and fattening of beef cattle, dairying and sheep raising, named in the order of importance. The extent of the livestock industries in the county is shown in the following figures taken from the Iowa Yearbook of Agriculture for 1922:

Horses, all ages	7,325
Mules, all ages	437
Swine, on farms July 1, 1922	65,400
Swine, on farms January 1, 1923	51,487
Cattle, cows and heifers kept for milk	7,948
Cattle, other cattle not kept for milk	16,936
Cattle, total, all ages	24,884
Sheep, all ages, on farms January 1, 1923	2,093
Sheep, shipped in for feeding, 1922	13
Sheep, total pounds of wool clipped	17,049
Poultry, total, all varieties	147,854
Poultry, number dozen eggs received in 1922	576,987

Hog raising is the most important livestock industry. Over 65,000 hogs were reported on the farms in July, 1922 and over 51,000 in January, 1923. This makes an average of between 50 and 60 on the farms of the county. Many of the herds are, of course, much larger than this. Most of the hogs raised are of mixed breeds, but the number of purebred herds is increasing. The most popular breeds are the Duroc-Jersey, big-type Poland-China and Chester White. There are a few herds of Hampshires and one herd of Berkshires. The hogs are sold on the markets at Chicago, Omaha and St. Paul.

The raising and feeding of beef cattle is practiced extensively in the county. Most of the cattle marketed are home raised. Feeders are brought in, however, from Sioux City, Omaha, and St. Paul. They are fed from late summer to early spring and sold on the Chicago market. Most of the cattle are of mixed breeds but purebreds are becoming more common. Shorthorns are the most popular but there are also herds of Herefords and Angus.

Dairying is practiced chiefly as a side line on most farms. In the vicinity of local markets, however, it is developing into an important industry. The dairy herds vary widely in size, some of them numbering 25 to 30 head. On the average, the local creameries report that their supply comes from herds of 8 to 10 cows. The majority of the milk cows are of mixed breeds but there are some purebreds, chiefly Holsteins. There are a few purebred Guernseys in the county. The milk and cream produced is largely utilized on the local markets. The greater part of the butter is shipped out of the state.

Sheep raising is carried on principally in the more rolling sections of the county, near the main streams and lakes. The industry is not very extensively developed in the county. A very few sheep are shipped in for feeding. The production of wool provides some income on a few farms.

The raising of horses and mules is practiced on many farms but the industry is relatively unimportant. A few horses are raised on most farms and a few produce mules. Work horses are usually of a good draft type but little attention is given to purebreds. The few purebreds in the county are of the Percheron, Shire or Clydesdale breeds. There are usually a few horses sold each year.

Poultry raising is practiced on most farms and in some cases, considerable income is derived from the sale of poultry products. In 1922 there were over 575,000 dozen eggs produced. Poultry produce is disposed of, mainly on the

local markets. If more attention were given this industry it might be developed to a more profitable extent in the county.

The value of the land in Dickinson county is rather variable, depending on the location with reference to towns and to railroad facilities and also on the improvements on the farms and on the soil and topographic conditions. The prices range from $100 to $350 per acre. The average price would probably be around $250 per acre.

CROP YIELDS MAY BE INCREASED IN DICKINSON COUNTY

In general, crop yields in Dickinson county are quite satisfactory, but proper methods of soil treatment will frequently bring about profitable increases. In some areas the land is still not properly drained and in such cases, crops do not give the best yields. The installation of tile has made many acres of land in this county highly productive and wherever land is too wet, profitable effects are brought about by tiling. The Webster types on the uplands and the Fargo soils on the terraces are very apt to be poorly drained. The Lamoure and Wabash soils on the bottoms are also poorly drained. It is particularly important in this county that sufficient tile of ample size and provided with adequate outlets, be installed in order to insure the removal of excess moisture from the soils which have been mentioned.

While many of the soils in this county are black in color and apparently well supplied with organic matter, it is necessary that all systems of management provide for the regular addition of fertilizing materials supplying organic matter. When the soils are lighter in color and more sandy in texture, or when the subsoils are sandy or gravelly, the need of organic matter is more evident. Farm manure is undoubtedly the most important fertilizer for all the soils of the county. It gives large effects on those types which are less well supplied with organic matter but it also brings about profitable crop increases on the richer, blacker types. Experiments and much farm experience have shown that farm manure is a very valuable fertilizer. It should not be applied on the heavier soils just preceding the growing of a small grain crop as it may cause the crop to lodge. It may be added to such soils with profit, however, at other points in the rotation. The proper care and application of farm manure to the soils of Dickinson county will aid materially in keeping them permanently productive and it will induce larger crop growth at the present time.

Green manuring is often followed with profit as a substitute for farm manuring or as a supplement to that practice. On the grain farm where there is little production of manure, it is very important that green manuring be practiced in order to provide for the addition of organic matter to the soil. It is often of value also on the livestock farm as there is rarely sufficient farm manure produced to supply regularly the needs of all the soils. Legumes should be used as green manures in preference to non-legumes as they have the ability, when well inoculated, of using the nitrogen of the atmosphere. In this way, they may add considerable amounts of nitrogen as well as organic matter to the soil and serve as nitrogenous fertilizers. Green manuring may be practiced to advantage in some cases in Dickinson county, especially on the lighter, sandy types and on those soils which are apt to be droughty.

Crop residues should always be thoroly utilized as they aid in keeping up the supply of organic matter. These materials should never be burned or otherwise destroyed as they are of considerable value on soils. They not only help to keep up the organic matter content, but they also return some of the plant food removed by the crops grown and thus aid in keeping the soil well supplied with necessary plant food constituents.

There is no large supply of phosphorus in any of the soils in the county and, indeed, the amount of this element is usually quite low. It seems probable, therefore, that additions of phosphorus fertilizers might be of considerable value. The evidence of tests on soils which are very much like those in this county is that phosphate fertilizers would probably give profitable crop increases at the present time. At any rate they will certainly be needed in the near future. It is recommended that farmers test the needs of their own soils for phosphorus by making an application to a small area. They may then apply the fertilizer to a large area with the assurance of profit. It is not yet possible to say definitely when phosphorus will be needed and actual tests in the field must be carried out before the farmer can be sure that the application will be of value. The relative value of acid phosphate and rock phosphate may also be determined on any farm by carrying out simple comparative tests. Field experiments are now under way in the county but they must be carried on over a period of years before conclusions can be drawn from them. The indications thus far secured point to the fact that phosphorus will be of value on many of the soils of the county and, hence, tests on the individual farms are suggested.

Erosion occurs to some extent in the county, particularly in the rolling phase of the Clarion loam. There is also some surface washing on other types. It is very desirable that some method of controlling or preventing the destructive action of erosion be adopted wherever it occurs. From among the suggestions given later in this report, some method may be chosen which will protect the soils from gullying and from surface washing which is often quite as destructive.

THE GEOLOGY OF DICKINSON COUNTY

The bed rock underlying the soils of Dickinson county is so deeply buried under the deposits of glacial till or drift that it has no effect on the soil character. Hence it is unnecessary to consider the geology of the area in any detail.

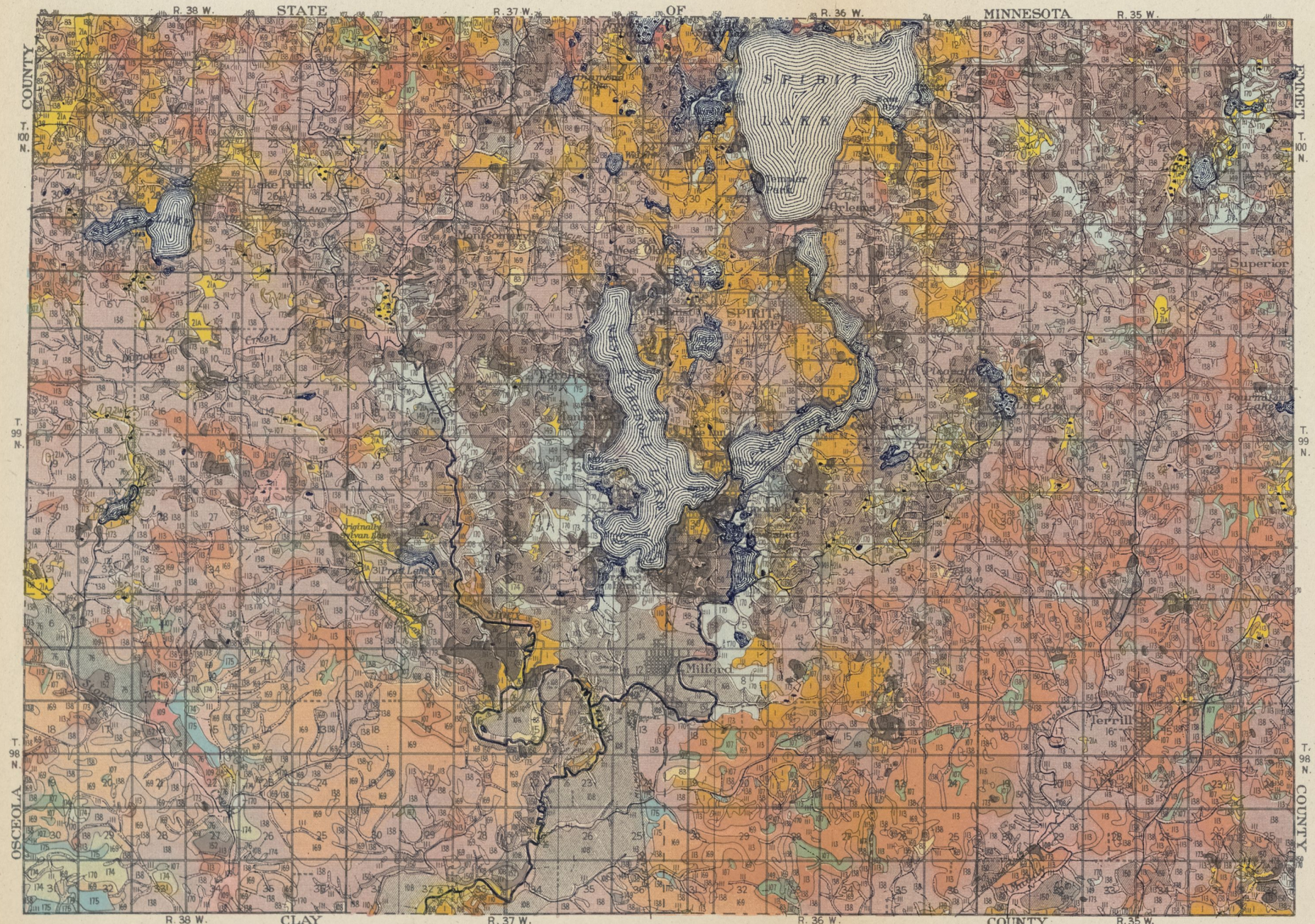
At least two great glaciers swept over the county during that period of time known as the glacial age, and upon their retreat, thick deposits of glacial drift or till were left, covering the surface of the land. This drift or till represents the material picked up by the glaciers in their forward movement over the surface of the land and it is, therefore, extremely variable in composition. When the ice melted and the glacier retreated, the mass of debris carried by the glacier was left behind, filling the old valleys and largely obliterating the topographic features of the land.

SOIL MAP OF DICKINSON 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 J. A. Elwell of the U. S. Department of Agriculture and J. L. Boatman 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.



LEGEND

Drift Soils

- 138 Clarion loam
- 150 Clarion loam (Rolling phase)
- 113 Webster silt loam
- 169 Clarion silt loam
- 1 Carrington loam
- 170 Pierce fine sandy loam
- 173 Pierce loam
- 107 Webster silty clay loam
- 83 Carrington silt loam
- 149 Clarion fine sandy loam
- 174 Dickinson loam
- 175 Dickinson fine sandy loam

Terrace Soils

- 108 O'Neill loam
- 76 Sioux loam
- 152 Fargo silt loam
- 110 O'Neill fine sandy loam
- 109 Fargo silty clay loam

Swamp and Bottomland Soils

- 111 Lamoure silty clay loam
- 21A Muck
- 26 Wabash silt loam

SCALE: 1 INCH 2½ MILES

AMERICAN LITHO. & PTG. CO. DES MOINES.

The first glacier, known as the Kansan, deposited a thick layer of drift which is now known as the blue clay. It is extremely variable in depth in different parts of the county, due probably to the filling up of earlier depressions in the land and the thinner deposition over the former knolls and higher land. The surface of the Kansan drift material was probably more or less level following the deposition of the till but during the years which elapsed before the later invasion of the county by the Wisconsin glacier some topographic features were undoubtedly developed. The blue clay of the Kansan drift is sometimes exposed in cuts but in most cases there is little influence of the material on the soil characteristics. None of the soils of the county are derived from this drift deposit.

The Wisconsin glacier left behind upon its retreat a deposit of drift which buried deeply the earlier Kansan deposit. The soils of the county are all derived from this Wisconsin drift material. Only very infrequently, on the rougher areas, where erosion has been active for many years, is there any evidence of the earlier drift deposits in the three-foot soil section. The Wisconsin drift is a pale yellow to light buff silt, clay and sand. It contains some stones and boulders. Thruout most of the area the drift material consists mainly of silt and clay. Sand and gravel occur more abundantly in the morainic region—that area which marks the edge of the glacier. In some places there are considerable accumulations of stony and gravelly material with pockets of sand or gravel. Some of the soils of the county are influenced to a large extent by the occurrence of these layers of so-called Wisconsin gravels within the three-foot soil section. Thruout most of the upland, sand occurs in sufficient amounts to give the soil a loamy texture. Stones and boulders occur also, but not in amounts sufficient to cause any difficulty in farming operations. The native Wisconsin drift is highly calcareous and in many places fragments of limestone occur. Much of the lime has been leached out of the surface soil, however, and in many cases the soils of the county show an acid reaction in the surface. The lower subsoils are usually still high in content of lime and effervesce freely with acid. The surface of the deposit has been considerably modified by weathering and by the growth of vegetation and the surface soils are mainly a dark brown to black in color. Drainage has been poor in some areas and there the accumulation of organic matter has been greater and there has been less removal of lime.

The depth of the Wisconsin drift layer is quite variable, ranging from a few feet to over 30 feet in different parts of the county. In general, the deposit is more than three feet in depth and no evidence of the earlier Kansan till is found in the soil section. The earlier topographic features of the Kansan glaciation were not entirely obliterated by the later deposit and occasionally on knolls and mounds there are remnants of the Kansan topography with layers of Wisconsin drift covering them. The gravel accumulations which sometimes occur in the three-foot section are probably of Wisconsin origin.

On the more level parts of the upland where drainage has been poor, the soils are blacker in color and usually high in lime. They are mapped in the Webster series. On the more rolling areas, there has been a smaller accumulation of organic matter and the soils are lighter in color. These soils are

mapped in the Clarion and Carrington series. The Clarion soils contain lime in the subsoil while the leaching has been more complete in the Carrington soils and all the lime has been removed from the 3-foot soil section. Both groups of soils are acid in the surface soil. Both are typically a dark brown in color. The Pierce soils occur in the morainic region and they are characterized by the occurrence of loose sand and gravel in the subsoil. They are dark brown in color in the surface soil. The subsoils are highly calcareous. The soils of the Dickinson series are distinguished by the occurrence of considerable sand and some gravel in the lower subsoil, probably derived from the Wisconsin gravels. The surface soils are a dark brown. There is no lime either in the surface soil or in the subsoil.

The terrace and bottomland soils are derived from the upland drift and they are very similar to the drift in character. The O'Neill soils have a dark brown to black surface soil and a sandy or gravelly subsoil. The Sioux soils are very similar except that the sandy, gravelly subsoil is calcareous, while the O'Neill subsoils contain no lime. Both of these series of soils occur on rather high elevations above overflow, and they represent glacial outwash terraces. The Fargo soils are developed on the low-lying, level areas of terraces. They are black in color, heavy in texture and poorly drained. The bottomland soils in the county are mapped in the Lamoure and Wabash series. The former resembles the Webster soil of the same texture and it is high in lime. The Wabash soil is similar in general character, except that it contains no lime either in the surface soil or in the subsoil. Both types are subject to overflow. Areas of muck occur in the county and these represent the occurrence of old lake beds or ponded areas or depressed undrained areas in the upland where there have been accumulations of vegetation and formerly peat deposits.

All the soils of the county are of recent geological formation and this fact is evidenced in the high content of organic matter, and the great natural fertility of the soil. There has been less removal of plant food constituents, less washing away of lime and less decomposition of organic matter, than has occurred in the older drift deposits to the east. The naturally poor drainage of the land, heavier subsoil conditions and more level topographic features have also aided in preventing losses of fertility constituents. When proper methods are followed in handling the soils of this county, it seems evident that very satisfactory crop yields should be secured.

PHYSIOGRAPHY AND DRAINGAGE

The topography of the land in the county varies from rolling to hilly in the northern part, to level to gently undulating in the southern part. A rough boundary between these two topographic divisions of the county may be drawn from a short distance south of Stony lake, southeast, passing south of Sylvan, Pratt and West Okoboji lakes, then southeast to section 15 of Milford township and then northeast along Bull ditch to the vicinity of Superior and then east to the county line. North of this boundary the land is rolling to rough. To the south it is smooth to very slightly undulating. The general slope of the county is toward the south, and the elevation ranges between 1,400 and 1,500 feet above sea level. The rougher portions of the county are

mapped in the rolling phase of the Clarion loam, the Pierce loam and fine sandy loam and to a lesser extent in the Clarion fine sandy loam. The roughest areas are found in the central part of the county and in the northeast part. The extreme southeastern part of the county is the more nearly level and the soils occurring there belong mainly in the Webster series. The areas of Clarion loam thruout the southern part of the county are less rolling than in the northern part and the Clarion silt loam is gently undulating in topography. Thruout the uplands the streams and intermittent drainageways cut the surface to a greater or less extent and bring about the pronounced topographic features which sometimes occur. In the northern part of the county the drainage system is more complete, while in the southern part there are fewer streams and intermittent drainageways and hence, the topography is generally more nearly level. Areas of muck and of the Webster soils occur in the depressions in the uplands. Along the streams there are areas of terrace soils and of bottomland types of the Lamoure and Wabash series.

The drainage of the county is brought about by the Little Sioux river and its tributaries and several small creeks. The chief tributaries of the Little Sioux are the West Fork Little Sioux and Dugout creek. Stony creek drains the southwestern part of the county and Muddy creek brings about the drainage of the southeastern part. The Little Sioux river flows thru a deep narrow valley. In many cases the bottomland is less than one-fourth of a mile in width. In its upper course, its channel is from 50 to 75 feet lower than the uplands and in its lower course in Okoboji township, the channel is 75 to 125 feet below the upland level. The other streams of the county flow thru

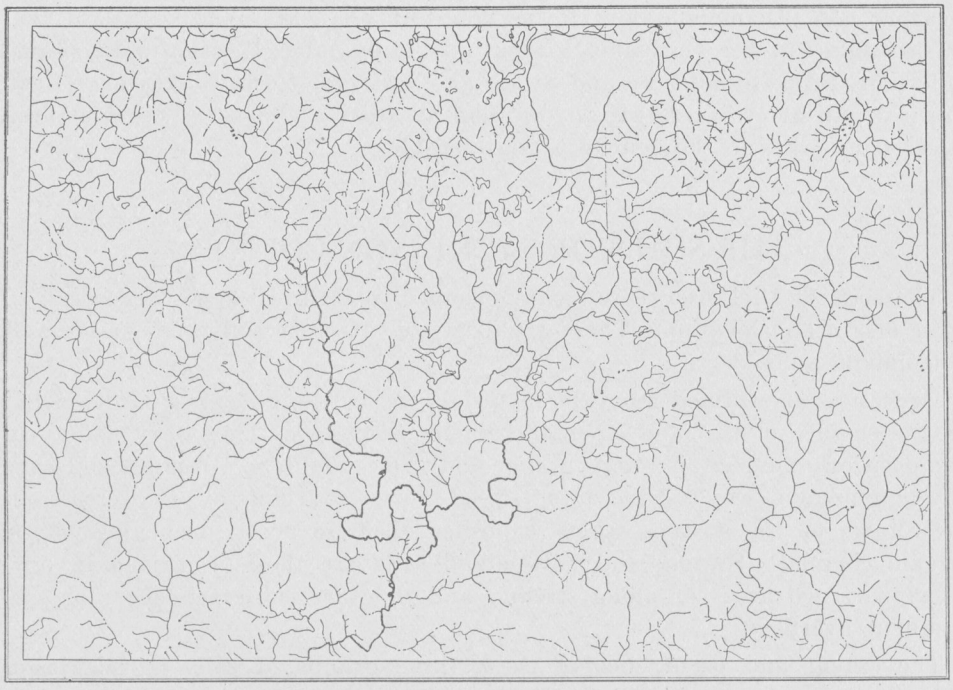


Fig. 3. Map showing natural drainage system of Dickinson county.

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

Soil Group	Acres	Percent of total area of county
Drift Soils	181,056	75.3
Terrace Soils	13,568	5.6
Swamp and Bottomland Soils	46,016	19.1
Total	240,640	....

relatively wide bottoms, but the total area of bottomland in the county is small, as the streams are few.

The natural drainage system of the county is poor as will be noted on the drainage map. Except for the Little Sioux river, the streams are small and the intermittent drainage lines are often widely separated. The lack of natural drainage is noted especially in the more level land in the southern part of the county. The large occurrence of the Webster soils indicates the extent of inadequate drainage. These soils are, in the main, poorly drained. Many areas of upland in the county have been reclaimed and made productive thru the installation of tile. The straightening and deepening of streams also aids in providing good drainage conditions by furnishing suitable outlets for the tile. Some drainage ditches have been installed and this has permitted better drainage of a considerable area. There are still areas in the county, however, where drainage is not adequate and until the thoro removal of excess water is provided for, crop yields will not be as satisfactory as they should be. Drainage is the first treatment needed to make much of the land in the county produce the best crops.

There are many lakes in the county. The largest are Spirit Lake and West Okoboji and East Okoboji. Other smaller ones are Silver lake, Stony lake, Grovers lake, Diamond lake, Hottes lake, Marble lake, Welsh lake, Minnewashta lake, Lower Gar lake, Prairie lake, Lily lake, Pleasant lake, Fourmile lake, Little Spirit lake and Swan lake. Several former lakes have been drained and are now shown on the map as areas of muck. The total area covered by lakes in the county is considerable.

THE SOILS OF DICKINSON COUNTY

The soils of Dickinson county are grouped into three classes according to their origin and location. These are drift soils, terrace soils and swamp and bottomland soils.

Drift soils are formed from the materials carried by glaciers and deposited on the surface of the land when the glacier retreated. They vary widely in composition and contain sand, gravel and some boulders. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them or by a deepening of the stream channel. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams and they are subject to more or less frequent overflow.

The extent and occurrence of these three groups of soils in Dickinson county are shown in table II.

Slightly over three-fourths of the total area of the county is covered by drift soils, 75.3 percent. The area in terrace soils is small, amounting to 5.6 percent of the county. The swamp and bottomland soils are much more extensive, covering 19.1 percent of the county.

There are 18 individual soil types in the county and these with the rolling phase of the Clarion loam and the area of muck, make a total of 20 soil areas. There are 11 drift soils, not including the rolling phase of the Clarion loam. There are five terrace soils and three areas of swamp and bottomland soils, including the area of muck. The various soil types are distinguished on the basis of certain characteristics which are described in the appendix to this report and the names denote certain group or series characteristics. The textural character of the soils is shown in the second part of the names. The areas of the various soil types in the county are shown in table III.

The Clarion loam is the largest individual soil type. With the rolling phase which is much smaller in extent it covers 40.4 percent of the total area of the county. The rolling phase of this type is the fourth most extensive soil area, covering 7.8 percent of the county. The Webster silt loam is the third largest type in the county, covering 10.5 percent of the total area. The Clarion silt loam is fifth, covering 7.4 percent of the county. The Carrington loam is sixth, covering 5.8 percent of the county. The Pierce fine sandy loam is seventh, covering 4.2 percent of the total area. The Pierce loam and the Webster silty clay loam are small in extent covering, 2.4 and 1.7 percent of the county, respectively. The other drift types are all small in area and none of them cover more than one percent of the county.

The O'Neill loam is the largest of the terrace soils and covers 3.6 percent of the total area of the county. The other terrace types are all small in area,

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN DICKINSON COUNTY

Soil No.	Soil Type	Acres	Percent of total area of county
	DRIFT SOILS		
138	Clarion loam	78,144	40.4
150	Clarion loam (rolling phase)	18,944	
113	Webster silt loam	25,408	10.5
169	Clarion silt loam	17,792	7.4
1	Carrington loam	13,888	5.8
170	Pierce fine sandy loam	10,112	4.2
173	Pierce loam	5,888	2.4
107	Webster silty clay loam	4,032	1.7
83	Carrington silt loam	2,112	0.9
149	Clarion fine sandy loam	2,112	0.9
174	Dickinson loam	1,600	0.7
175	Dickinson fine sandy loam	1,024	0.4
	TERRACE SOILS		
108	O'Neill loam	8,640	3.6
76	Sioux loam	2,368	1.0
152	Fargo silt loam	1,088	0.5
110	O'Neill fine sandy loam	768	0.3
109	Fargo silty clay loam	704	0.2
	SWAMP AND BOTTOMLAND SOILS		
111	Lamoure silty clay loam	38,016	15.8
21a	Muck	7,168	3.0
26	Wabash silt loam	832	0.3
	Total	240,640	....

the largest, the Sioux loam, covers only one percent of the county. The Lamoure silty clay loam on the bottoms is the largest bottomland soil and the second largest soil type in the county. It covers 15.8 percent of the total area. The areas of muck and of Wabash silt loam are small, the former covering three percent of the county and the latter only 0.3 percent of the total area.

There is a rather definite relationship between the various soil types and the topographic features of the county. The typical Clarion loam has a gently undulating topography, while the rolling phase, as the name indicates, is rolling to rough. The Clarion silt loam and the fine sandy loam are very similar to the loam. The Carrington loam and the silt loam are likewise gently undulating to slightly rolling in topography. The Webster soils are all level to very slightly undulating. The Pierce soils occur on knolls and mounds and have a rough topography. The Dickinson soils are very similar to the Clarion and Carrington soils, except that they are somewhat more rolling. The terrace and bottomland soils are all quite level in topography.

THE FERTILITY OF DICKINSON COUNTY SOILS

Samples were taken for analysis from each of the soil types in the county. The more extensive types were sampled in triplicate while only one sample was taken of the minor types. All the samples were taken with the greatest care that they should represent the particular type and that there should be no effect from local conditions or from previous treatment of the soil. The samples were taken at three depths, 0 to 6 2/3 inches, 6 2/3-20 inches, and 20-40 inches, representing the surface soil, the subsurface soil and the subsoil, respectively.

Analyses were made for total phosphorus, total nitrogen, total organic carbon, total inorganic carbon, and limestone requirement. The phosphorus, nitrogen, and carbon determinations were made by the official methods, while the Truog qualitative test was used for the limestone requirement determinations. The figures given in the tables are the averages of the results of duplicate determinations on all samples and they represent, therefore, the averages of 4 to 12 determinations.

THE SURFACE SOILS

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

The amount of phosphorus present in the various soil types in the county varies from 862 pounds in the Dickinson fine sandy loam up to 1,857 pounds in the O'Neill fine sandy loam. The particular sample of muck analyzed in this work showed a high content of phosphorus, 1,885 pounds, but usually the supply of phosphorus in muck is not so large. The bottomland soils average higher in this constituent than the other soil groups as might be expected from the fact that there has been less crop growth on these soils and a small removal of plant food. The terrace soils show a somewhat higher phosphorus content than the upland drift soils, but the difference is not great, and is probably to be explained in the same way that the high content of the bottomland soils was accounted for. The variations within the different

soil groups seems to be greater than that between groups. The supply of phosphorus in soils depends on various conditions in the soil as well as upon their origin. Hence there are differences in the amount present in the different soil types, and these differences represent variations in the series characteristics and in the textural character of the soils. The relation to the soil series is not very clearly defined, altho the Webster soils and the Clarion and Carrington soils on the uplands seem to be better supplied than the Dickinson and Pierce soils. Among the terrace types, there is no apparent relation to the soil series. The O'Neill loam is higher than the Sioux loam and the Fargo silt loam is higher than the O'Neill loam, but the O'Neill fine sandy loam is higher than the Fargo silty clay loam and indeed the best supplied with phosphorus of any of the terrace soils. The Lamoure silty clay loam on the bottoms is richer than the Wabash silt loam, but the difference is probably mainly due to the texture of the soil.

In general there seems to be more relation between the phosphorus content of the soils and the texture than can be noted with any other of the various soil characteristics. Thus, the rolling phase of the Clarion loam is lower in phosphorus than the typical loam and the Clarion silt loam is higher than the loam. The Webster silty clay loam is better supplied than the silt loam of the same series. The Dickinson loam is richer than the fine sandy loam but the Clarion fine sandy loam is higher in phosphorus than the other types of that series and the Pierce fine sandy loam is higher than the Pierce loam.

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

Pounds Per Acre of Two Million Pounds of Surface Soil (0-6 2/3 inches)

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
138	Clarion loam	1,167	4,280	55,255	.....	4,666
150	Clarion loam (rolling phase)	1,037	3,400	40,413	.....	2,000
113	Webster silt loam	1,272	6,100	77,668	.....	4,500
169	Clarion silt loam	1,219	5,160	64,591	.....	2,500
1	Carrington loam	1,373	4,600	56,183	.....	5,000
170	Pierce fine sandy loam	1,427	3,880	52,306	.....	4,000
173	Pierce loam	1,185	3,640	39,312	.....	3,000
107	Webster silty clay loam	1,400	7,440	94,053	4,227	....
83	Carrington silt loam	1,400	5,080	58,804	.....	8,000
149	Clarion fine sandy loam	1,252	4,640	81,900	.....	5,000
174	Dickinson loam	1,266	4,440	52,416	.....	8,000
175	Dickinson fine sandy loam	862	3,400	47,783	.....	6,000
	TERRACE SOILS					
108	O'Neill loam	1,751	5,800	70,271	.....	5,000
76	Sioux loam	1,589	5,280	61,534	.....	7,000
152	Fargo silt loam	1,790	8,360	106,469	.....	2,500
110	O'Neill fine sandy loam	1,857	5,000	63,991	.....	6,000
109	Fargo silty clay loam	1,185	5,680	71,198	.....	2,000
	SWAMP AND BOTTOMLAND SOILS					
111	Lamoure silty clay loam	1,508	7,840	86,385	1,138	.....
21a	Muck	1,885	28,840	335,607	22,842	.....
26	Wabash silt loam	1,239	4,880	69,560	.....	2,000

The O'Neill fine sandy loam is higher than the loam of the same series but the difference is not great. The Fargo silt loam is higher than the Fargo silty clay loam. In general it seems that there is some relation between the texture of the soils and their phosphorus supply. The heavier textured types usually show more phosphorus. In some cases, however, there are variations which are apparently due to some other conditions and it seems that no definite conclusions can be drawn regarding the relation between the soil texture and the phosphorus supply. Heavier textured types which are level in topography and black in color are apt to be higher in phosphorus, but often other factors are in control and apparently a higher phosphorus content cannot be predicted upon these conditions alone.

Considering the results of the analyses as a whole, there is evidently no large supply of phosphorus in any of the soils of the county. It is certain, therefore, that phosphorus fertilizers will be needed on these soils in the near future if crop yields are to continue to be satisfactory. Furthermore, it is quite possible that the application of a phosphorus fertilizer might prove of value at the present time. The total amount of phosphorus present in a soil does not indicate how much of the element is available for plant use. Even if the total content is large, there may be a deficiency in available phosphorus. When this is true the soil will respond to the addition of a phosphorus fertilizer, containing the element in an available form. When the total content of phosphorus is low, however, the soil is more likely to be low in the element in an available form and there is more likelihood that a phosphorus fertilizer should be applied. Thus in the soils of Dickinson county, it seems quite probable that there may be an insufficient amount of available phosphorus and phosphorus fertilizers may prove of considerable value.

There are rather considerable amounts of nitrogen in all the soils in the county. The amounts present vary somewhat, ranging from 3,400 pounds in the rolling phase of the Clarion loam and in the Dickinson fine sandy loam up to 8,360 pounds in the Fargo silt loam. The muck, of course, contains a very large amount of nitrogen, which is to be expected from the character of the material. Again as in the case of the phosphorus, there is some relation between the nitrogen supply and the soil group. The bottomland soils are higher than the terrace or upland types while the latter contain on the average a smaller amount than the terrace soils. These differences are undoubtedly due to the fact that the upland soils have been cropped to a greater extent and there has, therefore, been a larger removal of the element. There are also some relations between the supply of nitrogen and the soil series. Thus the Webster soils are higher than the Clarion and Carrington types on the uplands. The latter soils are higher than the Dickinson and Pierce soils. The Fargo soils on the terrace are richer than the Sioux and O'Neill soils. The Lamoure silty clay loam on the bottomland is higher than the Wabash silt loam. This latter difference is of course due in part to the difference in texture in these soils. The characteristics which serve to distinguish soil series evidently have some effect on the nitrogen content. These characteristics include the topography, the color, the subsoil character and the origin of the soil. Evidently they all exert some effect on the content of nitrogen in the soil.

The relationship between content of nitrogen and soil texture is also indicated in these results. The rolling phase of the Clarion loam is poorer than the typical soil and the silt loam is higher than the loam and also higher than the fine sandy loam. The latter type is higher than the loam but the difference is small. The Webster silty clay loam is higher than the loam; and the Dickinson loam is higher than the fine sandy loam. The Pierce fine sandy loam and the loam of the same series are about the same in nitrogen content. The O'Neill loam is richer than the fine sandy loam but the Fargo silt loam is higher than the silty clay loam, due probably to some local difference in the two soils. In general, it seems that those soils which are higher in nitrogen are heavier in texture, blacker in color and more level in topography. Less thoro drainage is another factor which seems to be related to the nitrogen supply. All these conditions are recognized in the separation of the soils into series and into types. There are apparently some rather definite relations between the individual soil types and the nitrogen content.

While the soils of the county as a whole are quite well supplied with nitrogen, this element should not be overlooked in planning systems of permanent fertility. Farm manure is the most important fertilizing material supplying nitrogen to soils. It gives large effects on the crops grown on the soils of this county. It is the most valuable fertilizer which can be used.

On the grain farm, where little manure is available for use, the nitrogen content of the soils must be maintained by the use of legumes as green manures. On many livestock farms, the practice may also be followed to advantage as the amount of manure produced is often insufficient to supply all the soils regularly. Green manuring may be practiced in some cases in Dickinson county with beneficial effects. Crop residues also aid in keeping up the nitrogen content of soils as they return to the soil a part of the nitrogen removed by the crops grown.

The organic carbon content of soils measures the supply of organic matter. The color of the soil also indicates the amount of organic matter which is present. If the soil is dark in color there is a large amount of organic matter present. If the color is light, there is probably a deficiency in organic matter. There is a rather definite relation between the nitrogen content of soils and the organic matter supply and the color. Soils high in organic matter and black in color are usually well supplied with nitrogen. The color of soils is, therefore, roughly a measure of the organic matter content and of the nitrogen supply. The soils of Dickinson county are all dark in color and this indicates a considerable amount of both organic matter and nitrogen. The results of the analyses of the soils for organic carbon bear out this fact. While the amounts are large in all cases, there are some variations among the types. The range in organic carbon is from 39,312 pounds in the Pierce loam up to 106,469 pounds in the Fargo silt loam. The muck of course shows an enormous amount, far above that in any of the soil types.

The relations between the soils and the organic matter are very much the same as those noted in the case of the nitrogen as would be expected from the close relation which exists between the nitrogen and the carbon. The bottomland soils are higher than the terrace types and the latter are better sup-

plied on the average than the upland soils. The Webster soils are higher than the other upland types and the Fargo soils are richer than the other terrace soils. The Dickinson and Pierce soils average lower than the other soils on the uplands. Thus there are evidences of a relationship between the nitrogen supply and the soil series.

The most distinct differences in organic matter occur among the soil types, as was noted in the case of the nitrogen supply. The Clarion silt loam is higher than the loam; the Webster silty clay loam is higher than the silt loam; the Carrington silt loam is richer than the loam; the Dickinson loam is richer than the fine sandy loam; the O'Neill loam is higher than the fine sandy loam. In some cases other factors evidently come into play, for the Pierce fine sandy loam is higher than the loam and the Clarion fine sandy loam is richer than the silt loam. Similarly the Fargo silt loam is higher than the silty clay loam. In general, however, there seems to be some relation between the organic matter and the individual soil type. This relation is certainly due to the color of the soil, to the topography, to the texture and to the drainage of the soil, all characteristics which serve to distinguish soil types.

While the content of organic matter in the soils of the county is not low, methods of treatment should be followed which will permit the return of organic matter, if the supply is to be maintained. The addition of farm manure, the thoro utilization of crop residues and the turning under of leguminous crops as green manures are the treatments which should be followed in order to prevent the organic matter from becoming deficient. On the livestock farm, all the manure produced should be carefully preserved and applied to the soil. On the grain farm, it will be necessary to use legumes as green manures. In each case, all the crop residues should be returned to the land. By the use of these materials the soils may be kept up in organic matter and no deficit need ever occur.

The relation between the nitrogen and the organic carbon in soils indicates the rate at which decomposition processes are proceeding in the soil. It shows how fast plant food is being changed to an available form. If the relation is not satisfactory, there may be a low production of plant food constituents in an available form and crops may suffer. In most of the soils in this county, the relation between these two constituents is good but in some cases it is not at the best. Where this is true, the addition of farm manure is particularly desirable. Farm manure changes the relationship and stimulates the production of available plant food.

Only two of the soils in the county and the area of muck show any content of inorganic carbon in the surface soil. All the other soils are acid in reaction and need lime. In several cases the surface soils do not show any large acidity, but if the best growth of crops is to be secured, particularly legumes, the acidity must be neutralized by the addition of lime. In some of the types, as will be noted later, the subsoils are high in lime but if the surface soil is acid lime is needed. Lime in the subsoil will not supply the needs of the young plants and the best early growth of many legumes will not be obtained. Furthermore, lime is washed out of soils quite rapidly, when they are well drained and a need of lime in the future will not be obviated

by the presence of a small amount now. It seems very important that all of the soils in the county be tested for acidity before legumes are grown. Even the Webster silty clay loam and the Lamoure silty clay loam which show a small content of lime in the surface soil, will soon become acid and may be acid in some areas now.

THE SUBSURFACE SOILS AND THE SUBSOILS

The results of the analyses of the subsurface soils and the subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil per acre.

The content of plant food in the lower soil layers has little effect on the fertility of the soil unless there are very large amounts present, or a noticeable deficiency. In most cases, the lower soil layers in Dickinson county do not contain more plant food than is found in the surface soil and generally there is a slightly smaller amount present. Only in rare cases is there any considerable deficit. It seems that consideration of the analyses of the lower soil layers is unimportant. These analyses will not be considered in detail. Attention will merely be directed to the fact that they serve to confirm the previous conclusions.

It is evident that phosphorus will be needed on these soils in the near future. They might even be used to advantage in some cases now. Tho the supply of organic matter and nitrogen is considerable, it must be maintained. The use of farm manure, leguminous green manures and crop resi-

TABLE V. PLANT FOOD IN DICKINSON COUNTY, IOWA, SOILS
Pounds Per Acre of Four Million Pounds of Subsurface Soil (6 2/3″-20″)

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
138	Clarion loam	1,580	3,520	39,021	39,456	.....
150	Clarion loam (rolling phase)	1,804	3,600	42,496	16,908	.....
113	Webster silt loam	2,060	4,980	57,002	.....	3,000
169	Clarion silt loam	2,504	4,960	48,782	15,372	.....
1	Carrington loam	1,884	4,720	50,232	.....	5,000
170	Pierce fine sandy loam	1,884	4,640	53,508	.....	4,000
173	Pierce loam	2,174	2,800	32,866	.....	4,000
107	Webster silty clay loam	2,046	3,840	48,051	19,216	.....
83	Carrington silt loam	2,424	5,520	68,796	.....	8,000
149	Clarion fine sandy loam	2,236	5,600	68,250	.....	5,000
174	Dickinson loam	1,966	4,320	75,890	.....	6,000
175	Dickinson fine sandy loam	2,020	4,960	64,947	.....	6,000
	TERRACE SOILS					
108	O'Neill loam	2,936	5,840	69,888	.....	5,000
76	Sioux loam	2,936	7,280	90,963	.....	7,000
152	Fargo silt loam	2,410	8,120	107,775	.....	2,500
110	O'Neill fine sandy loam	2,854	4,800	55,582	.....	5,000
109	Fargo silty clay loam	2,020	7,200	97,188	.....	2,000
	SWAMP AND BOTTOMLAND SOILS					
111	Lamoure silty clay loam	2,236	5,600	74,600	2,276	.....
21a	Muck	3,204	47,520	542,092	25,748	.....
26	Wabash silt loam	2,208	6,560	96,751	.....	2,000

dues is strongly recommended. In several cases the subsurface soils show a lime content and in many of the soils the subsoil is well supplied with lime. The Clarion loam and the rolling phase of that type and the Clarion silt loam show a considerable amount of lime in the subsurface soil. The Webster silty clay loam and the Lamoure silty clay loam, both of which contained some lime in the surface soil show lime in the subsurface soil. In addition to these types, the Webster silt loam, the Pierce fine sandy loam, the Clarion fine sandy loam, the Fargo silt loam and the Fargo silty clay loam show a high lime content in the subsoil. As has been noted, however, a supply of lime in the lower soil layers does not obviate a need for lime in the surface soil, if it is acid. Lime rarely moves upward in the soil and the best growth of legumes will not be secured on a soil which is acid at the surface. In spite of the occurrence of lime in the subsoil, therefore, it is important that the soils of the county be tested for acidity. Smaller amounts of lime will probably be needed, if there is lime in the subsoil and later needs will not be so evident or possibly not shown at all, but to secure a good stand of a legume and good early growth, lime should always be used on an acid soil.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on the soils from Dickinson county in order to learn something regarding the fertilizer needs of the soils, and in the attempt to determine the value of certain fertilizing materials.

TABLE VI. PLANT FOOD IN DICKINSON 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					
138	Clarion loam	2,665	4,400	46,435	61,969	.....
150	Clarion loam (rolling phase)	2,586	2,880	7,506	198,060	.....
113	Webster silt loam	3,534	2,820	20,739	94,840	.....
169	Clarion silt loam	3,513	3,240	31,374	58,224	.....
1	Carrington loam	2,586	4,200	56,674	.....	3,000
170	Pierce fine sandy loam	3,231	1,680	18,636	81,282	.....
173	Pierce loam	2,586	3,480	30,303	.....	2,000
107	Webster silty clay loam	3,555	2,640	23,826	102,036	.....
83	Carrington silt loam	2,706	3,120	18,018	.....	3,000
149	Clarion fine sandy loam	3,273	2,160	14,526	143,541	.....
174	Dickinson loam	2,544	1,920	27,027	.....	3,000
175	Dickinson fine sandy loam	2,220	3,240	37,674	.....	6,000
	TERRACE SOILS					
108	O'Neill loam	3,675	4,920	55,692	.....	5,000
76	Sioux loam	2,667	4,200	46,683	.....	7,000
152	Fargo silt loam	3,352	4,860	56,166	68,321	.....
110	O'Neill fine sandy loam	3,192	1,920	58,968	.....	4,000
109	Fargo silty clay loam	3,354	5,160	55,674	77,823	.....
	SWAMP AND BOTTOMLAND SOILS					
111	Lamoure silty clay loam	3,030	2,640	29,916	2,844	.....
21a	Muck	3,756	15,240	205,809	83,434	.....
26	Wabash silt loam	1,806	5,640	92,547	.....	2,000

Fig. 4. Pot culture experiment with Clarion loam from Dickinson county.

These tests were conducted on the Clarion loam and the Webster silt loam, the two most extensive soil types in the county. The results of similar experiments on the same two types in Emmet county are also included in this report as the soils are very much the same in the two counties. The experiments on the Webster silt loam from Palo Alto county and on the Webster silty clay loam from Buena Vista county are discussed, too, as the results are applicable to the same soils in Dickinson county.

In all the experiments, the treatments tested included the use of manure, lime, rock phosphate, acid phosphate, and a complete commercial fertilizer. The amounts of these materials applied were the same as those used in the field and the results secured are directly applicable to field conditions. Manure was applied at the rate of 8 tons per acre; lime was used in sufficient amounts to neutralize the acidity of the soil and supply two tons additional; rock phosphate was applied at the rate of 2,000 pounds per acre; acid phosphate was added at the rate of 200 pounds per acre; and a standard 2-8-2 brand of a complete commercial fertilizer was applied at the rate of 300 pounds per acre. Wheat and clover were grown in the experiments, the clover being seeded about one month after the wheat was up. In some of the tests, the clover did not grow well and only the wheat yields are given.

The results of the experiment on the Clarion loam from Dickinson county are given in table VII. The figures given are the average of the results on the duplicate pots. Manure brought about a considerable increase in the yield of wheat. Lime in addition to manure gave a further increase. While lime ordinarily does not show large effects on the grain crops of the rotation, but is mainly effective on the legume, these results indicate that it may prove

Fig. 5. Clover on Webster silty clay loam, Buena Vista county.

beneficial on all the crops grown. The rock phosphate had little effect on the wheat but the acid phosphate and the complete commercial fertilizer gave large increases. The latter material gave a greater effect than the acid phosphate.

It seems evident that manure is of value on this soil and should be employed as far as it is available for use. Large crop increases will always be secured. The addition of lime is desirable. It may bring about increases in the yields of all crops grown and will certainly provide better conditions for the growth of legumes. There are indications that a phosphate fertilizer might be used profitably on the soil. Acid phosphate seems to be better than rock phosphate in this case but the results are not conclusive. Both materials should be tested on the farm before one is chosen. The complete commercial fertilizer did not give sufficiently larger increases than the acid phosphate to warrant its use. The greater cost of the complete fertilizer will probably make it less desirable for use than acid phosphate.

The results secured in the test on the Webster silt loam from Dickinson county are shown in table VIII. The yield on the manure pots was abnormal and is not included. The manure and lime gave a large increase in yield of wheat and this increase is undoubtedly largely attributable to the manure. Lime often shows small increases in this crop but the effects of manure are always much more definite. The rock phosphate showed little effect on the wheat but the acid phosphate and the complete commercial fertilizer both gave large gains. This soil will respond to applications of manure. It may be in need of lime in some cases and when this is true, additions of that material will prove beneficial, particularly on the legume grown. There is evidence of value from the application of a phosphate fertilizer and the acid phosphate seems to be preferable for use. Tests of both acid phosphate and

TABLE VII. GREENHOUSE EXPERIMENT. CLARION LOAM, DICKINSON COUNTY

Pot No.	Treatment	Weight wheat grain in grams
1	Check	8.073
2	Manure	9.505
3	Manure+lime	10.004
4	Manure+lime+rock phosphate	10,692
5	Manure+lime+acid phosphate	12.540
6	Manure+lime+complete commercial fertilizer	14.227

TABLE VIII. GREENHOUSE EXPERIMENT. WEBSTER SILT LOAM, DICKINSON COUNTY

Pot No.	Treatment	Weight wheat grain in grams
1	Check	8.501
2	Manure	.....
3	Manure+lime	11.148
4	Manure+lime+rock phosphate	11.650
5	Manure+lime+acid phosphate	13.558
6	Manure+lime+complete commercial fertilizer	13.362

TABLE IX. GREENHOUSE EXPERIMENT CLARION LOAM, EMMET COUNTY

Pot No.	Treatment	Wt. wheat grain in grams	Weight clover in grams
1	Check	9.906	19.0
2	Manure	11.398	33.0
3	Manure+lime	11.838	46.5
4	Manure+lime+rock phosphate	12.812	61.0
5	Manure+lime+acid phosphate	13.856	57.0
6	Manure+lime+complete commercial fertilizer	13.601	59.0

rock phosphate are recommended however, as these results are not entirely conclusive. The complete commercial fertilizer does not appear to be superior to the acid phosphate and hence the latter material is more desirable for use, owing to its smaller cost.

The results obtained on the Clarion loam from Emmet county very largely confirm those secured on the same type from Dickinson county. They are shown in table IX. Manure brought about a large increase in the wheat crop and the yield of clover was increased to a considerable extent. The addition of lime with the manure gave a small increase in the wheat but the

Fig 6. Wheat and clover on Webster silt loam from Palo Alto county.

Fig. 7. Pot culture experiment with Webster silt loam, from Dickinson county.

clover crop was increased very definitely. The rock phosphate, acid phosphate and complete commercial fertilizer all gave increases in both crops. The acid phosphate showed the greatest effect on the wheat while the rock phosphate gave the largest increase on the clover. The complete fertilizer did not show any greater effects than the acid phosphate on the wheat or any larger influence than the rock phosphate on the clover. Apparently manure is a most desirable fertilizer for use on this soil and will bring about large crop increases. Lime is needed when the soil is acid and will lead to large increases in the legume crop. It will also often bring about gains in the other crops grown. There is evidence of value from the addition of a phosphorus fertilizer. The complete commercial fertilizer had no better effect than the phosphates and hence it cannot be recommended for use.

The results of the test on the Webster silt loam from Emmet county are given in table X. They are very much the same as those secured on the same soil type from Dickinson county. Manure gave a large increase in the wheat crop. Lime with manure brought about a further increase. The phosphates and the complete commercial fertilizer showed some effect but the differences were not as large as in the previous test. It may be concluded, however, that manure is a most desirable fertilizer for use on this soil and that lime should be employed when the soil is acid. The application of a phosphorus fertilizer may increase crop yields and tests of the phosphate materials are recommended. There seems to be no evidence of any large

value from the addition of a complete commercial fertilizer and the phosphates seem to be preferable.

In table XI, there are given the results of the experiment on the Webster silt loam from Palo Alto county. Again the yield of wheat was increased by the application of manure. There was also an increase in the clover crop. The addition of lime had no effect on the wheat but brought about a large increase in the clover. The phosphates and the complete commercial fertilizer all increased the yields of the wheat and the clover, the acid phosphate showing the greatest effect on both crops. Once more the beneficial effects of manure are shown on this soil and the value of an addition of lime is indicated, as it brings about increases in the legume. The desirability of adding a phosphate fertilizer is also indicated. It is desirable that both acid and rock phosphate be tested on the farm to determine their relative value. The addition of a complete commercial fertilizer does not appear to be as desirable as the use of phosphates.

The results obtained in the experiment on the Webster silty clay loam from Buena Vista county are shown in table XII. On this soil, manure increased the yields of both wheat and clover. Lime with manure brought about a further increase. Acid phosphate showed the largest effect on the wheat, but no greater influence than the other materials on the clover. The rock phosphate did not seem to have any effect on the wheat, and the complete fertilizer had little influence on that crop. The addition of manure is apparently very desirable on this soil and while large amounts should not be

TABLE X. GREENHOUSE EXPERIMENT. WEBSTER SILT LOAM, EMMET COUNTY

Pot No.	Treatment	Weight wheat grain in grams
1	Check	9.792
2	Manure	13.706
3	Manure+lime	14.266
4	Manure+lime+rock phosphate	14.422
5	Manure+lime+acid phosphate	14.500
6	Manure+lime+complete commercial fertilizer	14.610

TABLE XI. GREENHOUSE EXPERIMENT. WEBSTER SILT LOAM, PALO ALTO COUNTY

Pot No.	Treatment	Wt. wheat grain in grams	Weight clover in grams
1	Check	23.0	45.36
2	Manure	28.0	49.89
3	Manure+lime	26.0	52.16
4	Manure+lime+rock phosphate	31.5	56.69
5	Manure+lime+acid phosphate	33.5	58.96
6	Manure+lime+complete commercial fertilizer	29.0	52.16

TABLE XII. GREENHOUSE EXPERIMENT. WEBSTER SILTY CLAY LOAM, BUENA VISTA COUNTY

Pot No.	Treatment	Wt. wheat grain in grams	Weight clover in grams
1	Check	26.56	29.5
2	Manure	29.46	36.0
3	Manure+lime	31.71	44.0
4	Manure+lime+rock phosphate	28.95	46.0
5	Manure+lime+acid phosphate	35.80	45.0
6	Manure+lime+complete commercial fertilizer	31.13	46.0

used just preceding the small grain crop, small applications at other points in the rotation will prove beneficial. Lime should be used when the soil is acid and there are indications of value from the use of a phosphate fertilizer. Tests to determine the effects of rock phosphate and acid phosphate are recommended.

FIELD EXPERIMENTS

Some field experiments have been started in Dickinson county but they have not been under way long enough yet to permit of conclusions. Such tests must be conducted over a period of years before the results are of significance. The data secured in these tests will be published later in a supplementary report.

Tests have been under way for some time in adjacent counties on soil types similar to those in this county and the results obtained in these field tests will be included here. They certainly indicate quite definitely what may be expected from the application of the same fertilizers to the same soils in this county. While these tests are still far from conclusive, the results are suggestive and as they are supported by the laboratory and greenhouse results and by the experience of some farmers, certain rather definite conclusions regarding the needs of the soils of the county may be drawn. The experiments which are described here include those on the Carrington loam on the Truesdale field in Buena Vista county, on the Webster silty clay loam on the Newell field and on the Storm Lake field in the same county and on the O'Neill loam in Clay county.

All these field tests are laid out on land which is thoroly representative of the individual soil types. The plots are 155′ 7″ by 28′, or one-tenth of an acre in size. They are permanently located by the installation of corner stakes and all precautions are taken in the application of fertilizers and in the securing of yields that the results be accurate. There are 13 plots in each series and the tests are so arranged that part of the plots represent the livestock system of farming and the other part the grain system. Plots 1 to 7 are in the livestock system and plots 7 to 13 are in the grain system.

Under the livestock system, manure is applied as the basic treatment and in the grain system plots, crop residues are employed instead of manure. The other fertilizer treatments tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. The manure is applied at the rate of 8 tons per acre once in a four-year rotation. The crop residue treatment consists of the turning under of the second crop of clover, the return of all the straw from the small grains, and the plowing under of the corn stalks. Sometimes the entire crop of clover is plowed under and in other cases only the seed of the crop is removed and the remainder of the crop is turned under. The straw is often stacked and applied to the land after it has undergone some decomposition. The cornstalks are cut with a stalk cutter or with a disk and plowed under. Limestone is applied to the soils in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is added at the rate of 2,000 pounds per acre once in the rotation. Acid phosphate is applied at the rate of 200 pounds

per acre and a 2-8-2 complete commercial fertilizer is added at the rate of 300 pounds per acre annually. In 1923, a 2-12-2 complete fertilizer was employed, 267 pounds being used, this amount supplying the same amount of phosphorus as that added in the 200 pounds of acid phosphate.

THE TRUESDALE FIELD

The results obtained on the Carrington loam on the Truesdale field, Series I are given in table XIII. This field is located in Buena Vista county. The Carrington loam is the same in general characteristics as the Clarion loam in Dickinson county, the only difference being that the Clarion has lime in the subsoil while the Carrington has none. The results on this field may be considered, therefore, to indicate quite definitely the effects which the same fertilizer treatments will bring about on the Clarion loam in Dickinson county.

Manure brought about a distinct effect on the corn in 1918, a smaller effect in 1919 and a large effect on the same crop in 1922. Very little effect was noted on the oats in 1920 but the crop in 1923 was increased to a large extent. The yield of clover on the manured plot in 1921 was evidently abnormal as there was a smaller crop than on the check plot. The beneficial effect of the lime in addition to the manure is apparent on all the crops grown, showing up quite as definitely on the corn and oats as on the clover. The value of applying lime to this soil evidently should not be measured entirely by its effect on the legume crop as it seems to bring about considerable increases in the other crops grown.

The rock phosphate, acid phosphate and complete commercial fertilizer brought about increases in crop growth in all cases except on the corn in 1922 and on the oats in 1923. The complete commercial fertilizer gave an increase in the latter year on the oats. The effects of the use of these fer-

TABLE XIII. FIELD EXPERIMENT—CARRINGTON LOAM—BUENA VISTA COUNTY. TRUESDALE FIELD—SERIES I.

Plot No.	Treatment	Corn, bu. per acre	1919 Corn, bu. per acre	1920 Oats, bu. per acre	1921 Clover tons per acre	1922 Corn, bu. per acre	1923 Oats, bu. per acre
1	Check	38.9	56.5	57.2	1.40	48.6	44.2
2	Manure	44.3	57.1	57.9	1.20	61.6	57.7
3	Manue+lime	46.4	58.1	59.2	1.60	64.0	61.2
4	Manure+lime+rock phosphate	54.4	58.7	64.7	2.45	63.2	60.0
5	Manure+lime+acid phosphate	49.6	58.7	64.9	3.30	61.6	61.2
6	Manure+lime+complete commercial fertilizer	49.6	58.7	64.7	3.10	63.7	68.0
7	Check	38.4	58.1	56.4	2.20	51.0	54.8
8	Crop residues	49.1	61.9	67.7	2.20	49.7	55.5
9	Crop residues+lime	51.2	66.6	66.0	2.20	50.6	54.5
10	Crop residues+lime+rock phosphate	58.9	68.8	68.1	3.10	61.6	60.0
11	Crop residues+lime+acid phosphate	57.6	67.2	76.8	2.90	64.1	64.5
12	Crop residues+lime+complete commercial fertilizer	62.9	66.1	77.6	3.00	60.4	77.0
13	Check	47.5	64.0	56.5	2.10	49.0	48.7

tilizers was most evident on the clover crop, the acid phosphate having the largest influence. Very definite increases were also noted on the oats in 1920. The complete commercial fertilizer did not have any larger effect than the phosphates in most cases and in general it did not show as large an influence as the acid phosphate. The acid phosphate seems to be somewhat more effective than the rock phosphate but the results are not definite enough to permit of conclusions.

The crop residues gave increases in crop growth in most cases but no large gains were noted, except on the oats in 1920 and on the corn in 1918. Lime with the residues showed small increases in most cases but not on all the crops. The clover was not increased which is unusual as lime generally brings about the largest effect on the clover crop. The yield on plot 9 was probably abnormal. Farm experience usually confirms the results noted on the clover in plot 3, where the lime gave a distinct increase in yield. The two phosphates and the complete fertilizer increased crop growth in all cases, the effects being very pronounced in most instances. The acid phosphate gave larger effects than the rock phosphate on the oats in 1920 and in 1922 and on the corn in 1923 while the rock seemed somewhat more effective on the corn in 1918 and 1919 and on the clover in 1921. The differences, however, are small and do not permit of conclusions. The complete commercial fertilizer showed greater effects than the phosphates in three cases but only on the corn in 1918 and in 1923 was the difference large. In general it does not seem that this material would be at all preferable to the acid phosphate.

Apparently phosphorus may be of value on this soil type, altho these tests are not conclusive. Tests on the farm will show whether phosphorus will prove profitable and whether acid phosphate or rock phosphate should be used. The complete commercial fertilizer does not seem to exert a sufficiently larger effect than the phosphates to warrant its use, owing to its greater cost.

The results obtained in Series II on the Truesdale field are given in table XIV. The clover winterkilled on plots 1 to 4 in 1919 and the yields were not secured. The yields of oats were very irregular on the livestock system plots in 1918 and do not show definite effects from the treatments practiced. Again the beneficial effect of manure is evidenced, definite increases being brought about in the oats in 1918 and in 1922, in the corn in 1920 and 1921 and in the clover of 1923. Lime in addition to manure increased the corn in 1920 and 1921 and the oats in 1922 but showed no effect on the other crops. The phosphates and the complete commercial fertilizer gave very definite increases in the corn in 1920, the oats in 1922 and the clover in 1923, but except for the complete commercial fertilizer showed no effect on the other crops. The differences between the effects of the three materials were small and no conclusions as to their relative values can be reached. There is evidence, however, that phosphorus with manure and lime may prove profitable on this soil. The complete commercial fertilizer did not produce crop increases sufficiently larger than acid phosphate to warrant its use.

The crop residues gave small increases in crop growth in most cases. Lime with the residues showed beneficial effects on all the crops except the oats in 1922. Lime may evidently bring about increases in general farm crops altho its effects are usually exerted mainly on the legumes. The phosphates

TABLE XIV. FIELD EXPERIMENT—CARRINGTON LOAM—BUENA VISTA COUNTY. TRUESDALE FIELD—SERIES II.

Plot No.	Treatment	1918 Oats, bu. per acre	1919 Clover, tons per acre	1920 Corn, bu. per acre	1921 Corn, bu. per acre	1922 Oats, bu. per acre	1923 Clover, tons per acre
1	Check	69.9		47.5	32.8	18.5	1.72
2	Manure	94.2	Clover	57.0	39.7	24.6	1.90
3	Manure+lime	91.2	killed	59.0	41.8	27.2	1.86
4	Manure+lime+rock phosphate	88.2	out	61.2	38.1	32.4	2.26
5	Manure+lime+acid phosphate	91.2	1.89	62.1	40.2	31.0	2.24
6	Manure+lime+complete commercial fertilizer	88.2	2.00	64.0	44.5	31.9	2.42
7	Check	85.1	1.59	57.1	36.3	23.6	1.93
8	Crop residues	89.7	1.98	58.5	32.9	31.2	1.98
9	Crop residues+lime	97.3	2.07	59.2	40.1	29.8	2.03
10	Crop residues+lime+rock phosphate	91.2	2.19	60.0	35.6	34.4	2.39
11	Crop residues+lime+acid phosphate	92.7	2.22	60.4	33.6	36.8	2.11
12	Crop residues+lime+ complete commercial fertilizer	95.8	2.37	61.9	35.5	37.3	2.39
13	Check	85.1	1.91	60.9	34.9	28.4	2.03

and the complete commercial fertilizer gave increases in the clover in 1919 and in 1923 and in the oats in 1922. Small effects only on corn were noted in 1920. Phosphorus is evidently of value on this soil. Tests of the two phosphates on the farm are very desirable. The complete commercial fertilizer seemed to have only a slightly greater influence than the phosphates, if any at all.

THE NEWELL FIELD

The results secured on the Webster silty clay loam on the Newell field in Buena Vista county are shown in table XV. This soil was basic when the experiment was started. Lime was not applied until the fall of 1920. For the first three years of the test, plots 2 and 3 and 8 and 9 are duplicates. It should be noted that in 1921 only the second cutting of clover was taken.

The influence of manure was very distinct on all the crops and was greatest on the corn in 1919 and 1923. The phosphates and the complete commercial fertilizer brought about gains in most cases. The greatest effects were shown on the corn in 1919 and 1922 and on the clover in 1921. The acid phosphate was more effective than the other materials on the oats in 1920 and on the corn in 1922. The rock phosphate was most effective on the corn in 1918 and the complete commercial fertilizer gave the greatest influence on the corn in 1919 and on the clover in 1921. The differences, however, were not extremely large in any case and conclusions can hardly be drawn as to the relative value of the various fertilizers. It is apparent that the application of phosphorus with manure to this soil is of value and tests on the farm are desirable. The lime applied in 1920 proved slightly beneficial to the clover in 1921 and to the corn in 1923. It is desirable to test the soil and determine its need for lime before legumes are grown.

The crop residues showed practically no influence on the different crops. Lime with the residues gave slight increases in the corn in 1922 and in 1923

TABLE XV. FIELD EXPERIMENT—WEBSTER SILTY CLAY LOAM—BUENA VISTA COUNTY. NEWELL FIELD

Plot No.	Treatment	1918 Corn, bu. per acre	1919 Corn, bu. per acre	1920 Oats, bu. per acre	*1921 Clover, tons per acre	1922 Corn, bu. per acre	1923 Corn, bu. per acre
1	Check	69.0	44.8	56.7	0.52	68.7	59.2
2	Manure	70.9	49.1	64.1	0.60	70.5	65.6
3**	Manure+lime	71.4	54.4	63.5	0.70	69.9	68.3
4**	Manure+lime+rock phosphate	74.1	61.4	69.7	0.70	74.1	69.3
5**	Manure+lime+acid phosphate	66.9	65.1	76.3	1.12	80.0	63.4
6**	Manure+lime+complete commercial fertilizer	66.4	70.9	68.9	1.20	74.4	67.7
7	Check	60.9	62.4	59.4	0.57	66.9	55.0
8	Crop residues	62.9	56.1	59.4	0.50	63.6	56.4
9**	Crop residues+lime	64.6	59.2	61.4	0.42	64.2	59.5
10**	Crop residues+lime+rock phosphate	63.4	60.8	56.7	0.52	67.3	65.9
11**	Crop residues+lime+acid phosphate	62.4	68.5	72.0	0.90	67.3	64.1
12**	Crop residues+lime+complete commercial fertilizer	61.3	65.3	71.3	0.92	67.0	65.8
13	Check	59.4	65.3	60.1	0.57	66.2	60.9

**Limestone applied October 11, 1920.
*Second cutting only.

but had no effect on the clover. Usually the latter crop is most affected and farm experience indicates that when the soil is acid lime should be applied. Crop increases resulted in most cases from application of phosphates and the complete commercial fertilizer. The corn in 1918 was not increased but in 1919 it showed large gains with acid phosphate and the complete commercial fertilizer. These two materials also benefited the oats in 1920 but the rock phosphate had no effect. Similarly in 1921, the clover was increased by the acid phosphate and the complete fertilizer while the rock phosphate showed no effect. In 1922 and 1923 all the materials gave increases. In most cases the acid phosphate and the complete commercial fertilizer brought about very similar effects. The former material is the most desirable inasmuch as the complete commercial fertilizer is much more expensive. It seems evident that on grain farms, the addition of acid phosphate may be profitable and tests on the farm are desirable.

THE STORM LAKE FIELD

The results obtained on the Webster silty clay loam on the Storm Lake field in Buena Vista county are shown in table XVI. This soil is basic and no lime has been applied. The yields on plots 2 and 3 and on plots 8 and 9 are, therefore, duplicates. No manure was added in 1918, as there is danger of this material causing oats to lodge. In 1922, acid phosphate and potassium chloride were applied to plots 3 and 9, the latter material being added at the rate of 50 pounds per acre in the spring.

Manure brought about an increase in the corn in 1919 and had much larger effects on the same crop in 1920 and in 1923. The clover crop in 1922 was

also increased by the manure. The phosphates and the complete commercial fertilizer increased crop yields in all cases, except with the rock phosphate and complete commercial fertilizer on the oats in 1922. In most cases the acid phosphate was superior to the other materials, but the complete commercial fertilizer gave slightly greater effects in 1918 and in 1920, and the rock phosphate had more influence on the oats in 1918. The differences were not very large, however, and definite conclusions cannot be drawn. It is evident that a phosphate may prove profitable on this soil, when applied along with manure. Tests with acid phosphate are recommended. The complete commercial fertilizer did not prove enough better than the acid phosphate to warrant its use. The muriate of potash showed no effect on the clover in 1922 or on the corn in 1923.

The crop residues showed effects on some of the crops, but only slight increases were noted. The phosphates and the complete commercial fertilizer increased the corn yield in 1920 and the clover in 1922. Little or no effects were brought about on the other crops. The muriate of potash increased the corn in 1923 but showed no influence on the clover in 1922. There are indications that acid or rock phosphate might be used to advantage on this soil under the grain system of farming. Tests on the individual farm are desirable. It is questionable whether a complete commercial fertilizer should be used as the acid phosphate seems to be of more economic value.

THE EVERLY FIELD. SERIES I

The results obtained on the O'Neill loam on the Everly field are given in table XVII. Manure increased the crops grown on this soil in all cases except with the corn in 1919 and in 1923. The greatest influence was noted on the clover in 1921. Large effects were also evidenced on the corn in 1922 and in 1918. Lime in addition to manure proved effective on all the crops.

TABLE XVI. FIELD EXPERIMENT—WEBSTER SILTY CLAY LOAM—BUENA VISTA COUNTY. STORM LAKE FIELD

Plot No.	Treatment	*1918 Oats, bu. per acre	1919 Corn, bu. per acre	1920 Corn, bu. per acre	1921 Oats, bu. per acre	1922 Clover, tons per acre	1923 Corn, bu. per acre
1	Check	73.0	54.7	48.2	45.1	0.75	51.0
2	Manure	73.0	54.1	57.3	42.2	1.01	60.7
3	Manure	73.0	57.6	58.1	36.3	1.29	65.1
4	Manure+rock phosphate	80.6	61.1	64.2	43.8	1.26	66.4
5	Manure+acid phosphate	74.5	66.4	76.5	51.8	1.42	68.5
6	Manure+complete commercial fertilizer	82.0	61.1	80.0	43.8	1.43	66.8
7	Check	70.0	71.5	66.6	40.9	1.10	55.8
8	Crop residues	85.1	75.7	67.7	49.1	1.08	63.3
9	Crop residues	76.0	70.1	67.2	41.1	1.25	70.7
10	Crop residues+rock phosphate	79.0	70.4	76.2	41.6	1.20	63.2
11	Crop residues+acid phosphate	73.0	64.0	76.2	45.5	1.23	63.1
12	Crop residues+complete commercial fertilizer	85.1	67.5	76.2	43.8	1.13	61.3
13	Check	79.0	67.5	67.7	39.7	0.86	51.9

Soil basic.
Acid phosphate and potassium applied to 3 and 9 in 1922.
*No manure applied.

TABLE XVII. FIELD EXPERIMENT—O'NEILL LOAM—CLAY COUNTY. EVERLY FIELD—SERIES I

Plot No.	Treatment	1918 Corn, bu. per acre	1919 Corn, bu. per acre	1920 Oats, bu. per acre	1921 Clover, tons per acre	1922 Corn, bu. per acre	1923 Corn, bu. per acre
1	Check	47.7	37.1	23.3	1.80	41.2	37.2
2	Manure	56.2	34.1	27.5	2.35	51.5	37.0
3	Manure+lime	56.4	38.0	28.9	2.60	53.1	42.3
4	Manure+lime+rock phosphate	56.0	40.3	33.6	2.94	53.3	41.7
5	Manure+lime+acid phosphate	59.2	39.0	32.6	3.28	54.7	39.2
6	Manure+lime+complete commercial fertilizer	55.4	40.9	30.9	2.97	55.4	38.3
7	Check	46.6	37.1	24.1	1.80	44.6	35.8
8	Crop residues	51.4	36.4	24.9	2.00	45.6	36.4
9	Crop residues+lime	54.1	37.0	24.4	2.22	44.5	38.7
10	Crop residues+lime+rock phosphate	57.0	37.3	28.2	3.20	51.5	38.8
11	Crop residues+lime+acid phosphate	56.2	35.1	30.6	3.13	51.9	41.3
12	Crop residues+lime+complete commercial fertilizer	57.6	37.9	26.8	3.00	51.7	37.3
13	Check	47.2	32.1	23.1	1.87	40.9	33.3

The clover was increased to the largest extent as would be expected but there were gains in the other crops which were quite definite. The phosphates and the complete commercial fertilizer gave increases in most cases. The clover crop in 1921 was increased to the largest extent by the use of these materials. The acid phosphate showed up particularly well. This latter material also gave the largest effect on the corn in 1918. The differences between the effects of the three materials were not great. The only conclusion permissible is that a phosphate fertilizer may be used with profit. Complete commercial fertilizer does not seem desirable because it gave no greater returns than the acid phosphate.

The crop residue treatment gave only small crop increases in most cases. Lime with the residues, however, showed gains in all the crops, the effect being most evident on the clover. The phosphates and the complete commercial fertilizer increased crop growth in all cases except on the corn in 1919. Rock phosphate and the complete commercial fertilizer did not increase the corn in 1923. The differences in the effects of the three materials were not definite. Acid phosphate seems better than the rock phosphate in some years while the latter had slightly greater effects in other years. The complete commercial fertilizer did not show any greater influence than the phosphates and hence it is less desirable. It seems that a phosphate might be used with profit on this soil under the grain system of farming. Tests on the farm are very desirable. In general, these results show that the O'Neill loam will respond to applications of manure and this material should be used as liberally as possible. When the soil is acid, which is usually the case, lime should be applied. Large crop increases will result from the use of lime. Clover will be effected most. Phosphate fertilizers may be used with profit and tests of acid phosphate and rock phosphate on the farm are recommended.

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

The field experiments which are located in Dickinson county have just been started and data will not be available from them until a later date. They must be carried on over a period of years before conclusions regarding the value of various fertilizer treatments can be drawn. The results secured in these tests will be published later in a supplementary report. For the present, the suggestions offered regarding the use of fertilizers in this county are based on results of the laboratory tests, greenhouse experiments and field tests in other counties on the same soil types, as discussed in previous pages. The results secured in adjacent counties on the same soils which occur in Dickinson county may be considered to indicate quite definitely the needs of the soils in this county. No recommendations are made which have not been tested to some extent by individual farmers and proved of value by practical experience.

MANURING

The soils of Dickinson county are, in general, dark in color and the analyses show a high content of organic matter. This is particularly true of the upland soils. The level areas of Webster soils on the uplands are black in color and very rich in organic matter. It would not be expected, therefore, that the soils of this county would respond to applications of manure to such a pronounced extent as is the case with the lighter colored soils, poorer in organic matter, which occur in other counties. The use of manure, however, greatly increases crop yields. The more rolling uplands and the terrace types with sandy subsoils are benefited most by manure. But the more level, black upland types also give large response to manure. There is no fertilizing material which brings about anything like as large effects as manure and, indeed, other fertilizers do not show their best effects, unless manure is used as a basic treatment. The use of farm manure on the soils of the county is strongly recommended, in order to secure the best crop yields and to keep the soils permanently productive.

On the grain farm, where there is little manure produced and on many livestock farms, where there is not enough manure to supply all the land, some other material supplying organic matter must be used. In such cases green manuring with legumes is recommended as the best and cheapest method of adding organic matter to the soil. Leguminous crops are most desirable as green manures because they have the ability, when well inoculated, of taking nitrogen from the atmosphere. They serve to increase the nitrogen content of the soil, as well as to add organic matter. Non-legumes are sometimes used as green manures and while they supply organic matter, they do not add any nitrogen.

Green manuring must be practiced on the grain farm as a substitute for farm manure. On the livestock farm, it may often be desirable as a supplement to farm manure. The practice may be followed with profit in some cases in Dickinson county, but it should never be practiced blindly or carelessly as it may bring about undesirable effects in the soil. It is never de-

sirable to turn under a heavy green manure crop on land which is dry as it may interfere seriously with the moisture conditions. Advice regarding green manuring under special conditions will be given by the Soils Section upon request.

Thoro utilization of all crop residues, such as straw and stover, is very necessary under all farming conditions in order to aid in keeping up the supply of organic matter. Residues should never be burned or otherwise destroyed. They are of large value for use on soils. On the livestock farm, they may be used for feed or bedding and returned to the soil with the manure. On the grain farm they may be applied directly to the land or stored and allowed to decompose partially before application. On the grain farm the use of crop residues is particularly important but they should never be wasted on the livestock farm.

LIMING

Practically all of the surface soils in Dickinson county are acid in reaction and hence in need of lime for the best growth of crops, and particularly legumes. The Webster silty clay loam on the uplands and the Lamoure silty clay loam on the bottoms are the only types which contain any lime in the surface soil. Many of the types show a lime content in the subsurface soil or in the subsoil but this does not obviate a need of lime when the surface soil is acid. Lime rarely moves upward in the soil and, on the other hand, there is a constant removal of lime from the soil thru washing away in the drainage water as well as thru utilization by crops. If the best early growth of crops is to be secured, lime must be applied to neutralize any acidity in the surface soil. The later needs of the crops may be supplied by the lime in the lower soil layers. The presence of lime in the subsoil, now, does not mean an adequate supply for the future, however, owing to the losses which constantly occur and which may be considerably accelerated by thoro drainage and heavy cropping.

Soils which are acid in reaction do not permit the best growth of crops. Legumes are especially sensitive to acidity and frequently refuse to grow in an acid soil. Other crops are less affected and often good yields of such crops as corn and oats are secured on rather acid soils. But the application of lime to acid soils brings about large crop increases and these often occur with the corn and small grain crops as well as with the legumes. The use of lime is certainly a most profitable practice. This conclusion is confirmed by much experimental data and by considerable farm experience. The experiments reported earlier in this report show that additions of lime to some of the more extensive soil types in this county lead to large crop increases. Farm experience has shown similar benefits from the application of lime to soils which are acid.

The only way to determine whether or not soils need lime is to test them. Farmers may test their own soils for acidity or need of lime, but it will be more satisfactory if they will send a small sample of their soil to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge.

The lime requirement of soils is extremely variable and soils of the same type do not show the same needs. Every field should be tested before lime is applied. Even averages from many tests cannot be considered to show the lime requirement of any soil. The data given earlier in this report merely indicate the needs of the various soil types in this county and they should not be used as the basis for applications. One application of lime to soils will not suffice for all time and it is recommended that the soil be tested once in a rotation, preferably preceding the legume crop.

Limestone is the cheapest and best material to use in Iowa and it may be secured at various points in the state. Freight charges constitute the largest part of the cost of limestone and hence it is desirable to secure it from the nearest source.

The testing of soils and use of lime is important in Dickinson county and farmers should see that their soils are in the best reaction and contain the proper amount of lime if they wish to secure the best crop yields and keep their soils permanently productive.

THE USE OF COMMERCIAL FERTILIZERS

The soils of Dickinson county are not very well supplied with phosphorus. In most cases the content of this element is so low that phosphorus evidently will be needed in the very near future. It may in some cases be necessary at the present time.

The results which have been secured up to the present, do not permit of definite recommendations regarding the use of phosphates but they do indicate that they may often be used with profit. Hence farmers are urged to test their own soils for the need of phosphorus. They may apply a phosphate to a small area and compare the yields secured with those obtained on a similar untreated area in the same field.

Two phosphorus fertilizers are available for use, rock phosphate and acid phosphate. The former is cheaper but it must be applied in much larger amounts as it contains the element in an unavailable, or slowly available form. The acid phosphate contains the phosphorus in an available form and a smaller application is all that is needed. The material, however, is much more costly than the rock phosphate. The tests which are now under way in the county to determine the relative value of these two fertilizers do not permit a choice to be made at the present time. Farmers are urged to test both phosphates on the farm and thus determine for their own conditions which material will prove more profitable. Directions for the carrying out of such tests are given in Circular 82 of the Iowa Agricultural Experiment Station, and the Soils Section will advise farmers who wish to carry out such tests. Tests of phosphorus fertilizers are very desirable in Dickinson county and it is hoped that many farmers will carry out tests as suggested and will make their results known.

The supply of nitrogen in the soils of the county is considerable but this element must not be overlooked in planning systems of permanent fertility. If the supply is to be kept up, some means must be employed to return nitrogen to the soil. While the soils are not in immediate need of nitrogen, the supply must be maintained.

Manure is a very important fertilizer from the standpoint of keeping up the nitrogen content of soils. When it is used, there is less need for other nitrogenous materials. Manure alone, however, will not maintain the nitrogen supply, as on the average livestock farm, the amount produced is not adequate to permit of large applications to all the land regularly. On the grain farm, some other material supplying nitrogen must be used. Legumes are able to utilize the free nitrogen of the atmosphere and when they are well inoculated, as they should be, they may add considerable amounts of nitrogen to the soil, if the entire crop is plowed under as a green manure. Green manuring with legumes is the cheapest and best method of supplying nitrogen to soils on the grain farm and it is a very desirable supplement to manure on the livestock farm. Crop residues aid in keeping up the content of nitrogen in soils and the thoro utilization of these materials is strongly recommended.

Commercial nitrogenous fertilizers cannot be recommended for general farm crops as the nitrogen supplied by legumes is cheaper and better. This is due to the fact that the legumes supply organic matter as well as nitrogen. In small amount, as top dressings, commercial nitrogenous fertilizers may possibly be used in some cases to advantage, but tests on small areas should always be carried out before such materials are applied to any considerable areas. If such tests show profit from the use of the fertilizers there is no objection to their use.

According to earlier analyses of the soils of the state, there seems to be a large amount of potassium present and it does not appear likely that potassium fertilizers will be needed for general farm crops. If the soils are kept in the best condition, with regard to drainage, aeration, and organic matter content, there should be a sufficiently rapid production of potassium in an available form to supply the needs of crops. When the soil is properly handled, therefore, it does not seem probable that potassium fertilizers would prove profitable. Farmers may test their value however, if they wish, by making applications to small areas and if profitable effects are secured the fertilizer may be applied without fear of injury to the soil.

Complete commercial fertilizers contain the three essential plant food constituents, nitrogen, phosphorus and potassium. The use of these materials is probably not desirable in this county, as the soils are well supplied with potassium and the nitrogen content of the soils may be more cheaply maintained by the proper use of farm manure and leguminous green manures. Phosphate fertilizers, supplying only the one element, phosphorus, are more desirable and will probably be more profitable. The tests which have been discussed in previous pages indicate that quite as large results are secured from the application of phosphates as from the addition of a complete commercial fertilizer. Farmers who are interested in the use of complete commercial fertilizers may test them in comparison with acid phosphate and thus learn for their own conditions whether or not the complete brand will be more profitable.

DRAINAGE

The lack of adequate drainage in many of the soils in Dickinson county has already been noted. The Webster soils on the upland, the Fargo soils on the terraces and the Lamoure and Wabash soils on the bottoms are all apt to be too wet and to need more thoro drainage. These soils are all naturally rich and they may often be made much more highly productive if they are well drained. Soils which are too wet will not permit of the best crop growth and the first treatment needed is drainage. Other treatments will not prove profitable on wet soils and fertilizers should not be applied until the soil is adequately drained.

Considerable attention has been devoted to drainage in Dickinson county and large areas have been reclaimed from almost complete unproductivity by the installation of tile and the digging of drainage ditches. Straightening and deepening natural drainage channels has also aided materially in bringing about thoro drainage. But there are still areas in the county where the drainage is not sufficient to permit the best crop growth. Tile of ample size should be provided, adequate outlets are necessary and sufficient tile to carry away the water from the land should be laid. The expense involved may be considerable but the results secured will more than warrant the outlay. In order to secure the best crop yields, land must be well drained. Until adequate drainage is accomplished, other soil treatments will probably fail to give desirable returns.

THE ROTATION OF CROPS

The continuous growing of any one crop will very quickly reduce the fertility of the soil. Often, the profit from one crop leads the farmer to grow that crop continuously on his land and after a few years, he finds that the yields are very rapidly declining. The rotation of crops is a most desirable practice on all farms. Even if some crops are included, which are not very profitable, the income from the land over a period of years will be greater. Experiments and much farm experience have very clearly shown that rotating the crops increases the income over a period of years and the soils will be kept more productive.

There are many rotations which may be followed and no one rotation can be recommended for use under all conditions. No special studies of crop rotations have been carried out in Dickinson county but there are some good rotations which have been found to be of value in the state and these are listed below. The rotations suggested may be modified to fit the particular conditions, and indeed almost any rotation may be practiced, provided it contains the money crops and a legume.

The following are important rotations which are in use in the state:

1. SIX-YEAR ROTATION

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

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

2. FOUR OR FIVE-YEAR ROTATION

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

3. FOUR-YEAR ROTATION WITH ALFALFA

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

4. FOUR-YEAR ROTATIONS

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

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

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

5. THREE-YEAR ROTATIONS

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

First Year —Corn.
Second Year—Oats or Wheat (with clover).
Third Year —Clover.

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

THE PREVENTION OF EROSION

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

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and the crop growth prevented. Gullying is more striking in appearance but it is less harmful and

it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes.

Erosion occurs to some extent in the county, in the rolling phase of the Clarion loam, to a lesser extent in the other Clarion types, and in the Carrington, Pierce and Dickinson soils. Gullies frequently occur in the rolling phase Clarion loam and there is considerable washing away of the surface soils in the other types. It is very important that means be taken to protect the soils from erosion.

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

EROSION DUE TO DEAD FURROWS

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

"Plowing In." It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas this process may be quite effective. In the more rolling areas, however, it is best to supplement the plowing in with a series of "staked in" dams or earth dams.

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

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in dead furrows.

SMALL GULLIES

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

Checking Overfalls. The formation of small gullies or ditches is practically always the result of overfalls. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts.

"Staking In." The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the staking in operation recommended for the control of dead furrow gullies.

The Straw Dam. A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used.

The Earth Dam. The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. In general, it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

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

The Adams Dam. This dam is practically the same as the Christopher or Dickey dam. In fact the principle of construction is identical. In some sections the name "Adams Dam" has been applied and hence it is mentioned separately.

The Stone or Rubble Dam. Where stones abound they are frequently used in constructing dams for the control of erosion.

The Rubbish Dam. The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method.

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

Sod Strips. The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly.

The Concrete Dam. One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage. The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion.

LARGE GULLIES

The erosion in large gullies which are often called ravines may in general be controlled by the same methods as in the case of small gullies. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

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

Straightening and Tiling. The straightening of the larger streams in bottomland areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed.

Trees. Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable.

HILLSIDE EROSION

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

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

Growing Crops. The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also quite desirable for use in such locations.

Contour Discing. Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour-discing" and it has proven quite satisfactory in many cases in Iowa.

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

Deep Plowing. Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains.

INDIVIDUAL SOIL TYPES IN DICKINSON COUNTY*

There are 18 soil types in Dickinson county and these together with the rolling phase of the Clarion loam and the area of muck make 20 separate soil areas. These are divided into three large groups according to their origin and location and these groups are drift soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are 11 drift soils and these with the rolling phase of the Clarion loam make a total of 12 soil areas. They are classified in the Clarion, Webster, Carrington, Pierce and Dickinson series. The total area covered by the drift soils amount to 75.3 percent of the county.

CLARION LOAM (138)

The Clarion loam is the largest individual soil type in the county. With the rolling phase which is much smaller in extent, it covers 40.4 percent of the total area of the county. It occurs on the uplands in all parts of the county, being developed extensively in the northern townships, where it is the chief upland type. There are no extensive individual areas of the type, but everywhere, thruout the county, it is cut into small areas by the other upland types and by areas of muck, and Lamoure silty clay loam.

The surface soil of the Clarion loam is a dark brown to black mellow loam, 12 to 14 inches in depth. The subsurface soil to a depth of 16 to 18 inches is a light brown to brown friable, heavy silt loam. The subsoil is a light brown to yellow grayish-brown silty clay loam. The subsoil is moderately to highly calcareous, and the typical gray color of the lower soil layers is due to the content of lime. Occasionally there is some lime in the surface soil. Small quantities of sand are sometimes found. The texture of the surface soil is quite variable, ranging from a light sandy loam to a loam in some areas and in others, varying from a light loam to a heavy loam or in places a silt loam. The more sandy areas occur in the so-called morainic region and in these rougher areas there is a larger occurrence of sand, pebbles and boulders. Thin layers of sand and gravel are sometimes found in the subsurface soil or in the subsoil, and these are more common in the morainic areas. There are small areas of other upland types included within the Clarion loam as they are too small to show on the map. These areas are made up of Clarion fine sandy loam, the silt loam and the rolling phase of the Clarion loam and the Carrington soils. The boundary lines between this soil and the other upland types is often very difficult to draw and particularly in the case of the rolling phase. In some places the separation of the types has been made rather arbitrarily.

In topography, the Clarion loam is typically gently rolling. In the morainic region, a more rolling surface occurs. Areas in Superior township and in the eastern part of Diamond Lake township contain some ridges with rolling slopes and narrow crests. These represent the more rolling occurrence of the type. In general the type is characterized by long gentle slopes and broad-crested elevations. The soil is generally well drained and only

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

Fig. 8. Clarion loam topography, Dickinson county.

in the more level areas is tiling apt to be needed. In these areas, the streams and drainageways are sluggish and the soils are not drained sufficiently rapidly. In the more rolling areas the natural drainageways are not well developed and often they lead into depressions which have no outlet and hence sloughs are formed. The areas of muck which occur frequently thruout the Clarion loam indicate the occurrence of these poorly drained areas.

Practically all of the type is utilized for agricultural purposes, the larger portion being in cultivated crops. Timber occurs only in narrow areas along the lakes and streams. The more rolling areas are utilized for pasture. Corn is the most important crop, yielding 35 to 45 bushels per acre. Tame hay is second, yielding on the average, 1½ to 2½ tons per acre of timothy and clover mixed, 1½ tons for timothy alone and 2 to 2½ tons for clover alone. Clover and timothy mixed is the most commonly grown hay crop. Oats is third in importance, yielding 30 to 35 bushels per acre. Some wheat is grown, average yields amounting to 12 to 15 bushels per acre. Barley is grown to some extent and yields 20 to 30 bushels per acre. On some areas alfalfa is grown and yields of this crop average 2½ tons per acre. Timothy is sometimes grown for seed yielding 3 to 8 bushels per acre. Some clover is also grown for seed and 75 to 100 pounds per acre are secured.

The Clarion loam is naturally a fertile soil but crop yields may be increased thru the adoption of proper methods of soil management. The application of farm manure is especially desirable as this material brings about large crop increases. The experiments reported in previous pages have shown how effective farm manure may be in increasing crop growth and in keeping the soil permanently fertile. Where manure is not produced in sufficient amounts to supply to the soil, it may often be desirable to turn

under a legume as a green manure. By the use of these materials, the supply of organic matter and nitrogen in the soil may be maintained. The type is acid in reaction in the surface soil in most cases, and while there is lime in the subsoil, it is necessary to apply lime if the best growth of legumes is to be secured. The use of lime may often bring about increases in yields of other crops also, as is indicated in the experiments described earlier in this report.

The soil is not high in phosphorus and the application of a phosphorus fertilizer may be of large value. While definite recommendations along this line cannot be made at the present time, the experiments discussed earlier in this report indicate that there is every reason to believe that phosphorus is needed on this soil for the best crop growth. Farmers are urged to test the need of their own soil for phosphorus and also to determine, by field tests, whether rock phosphate or acid phosphate should be used. Drainage of the type is sometimes necessary and in some areas precautions are needed to prevent injury to the land from erosion.

CLARION LOAM (ROLLING PHASE) (150)

The rolling phase of the Clarion loam is of minor importance in the county, covering 7.8 percent of the total area. The type is extensively developed in the northern part of the county, near the lakes and larger streams. The largest areas occur north of Swan lake in Superior township, between Bull ditch and East Okoboji lake in Center Grove township and between the Little Sioux river and West Okoboji lake in Lakeville township. Numerous other small areas occur, associated with the typical Clarion loam and with the Pierce soils, and the Dickinson types. The areas generally separate the more gently rolling uplands from the stream bottoms.

The surface soil of the rolling phase Clarion loam is a dark brown to black moderately loose loam, 10 to 12 inches in depth. The subsoil is a brown to dark yellowish-brown, friable silty clay loam to silty clay. At the lower depths, the subsoil becomes a more plastic silty clay loam, and the color changes to a light brown or pale grayish-brown. There is always a more or less large amount of sand and gravel. The subsoil is usually highly calcareous, and this leads to the gray color. In some areas where there is less lime present the subsoil is more of a yellow in color. Boulders are found thruout the soil and occasionally on the surface. When associated with the Pierce soils, the subsoil of the phase is a light to heavy sandy clay, containing shallow layers of sand and gravel at varying depths. Often it is difficult to draw a definite boundary between the phase and the typical Clarion loam and in some instances, the boundaries have been placed rather arbitrarily. In general the phase is distinguished from the typical soil, by its lighter color, the greater variation in texture in the surface soil, and the greater occurrence of sand and gravel in the subsoil. These differences are of course secondary to the topographic difference, upon which the separation is typically based, but in some areas there is a gradual change from the rolling topography of the phase to the gently rolling topography of the typical soil, and the soil difference is of aid in making a separation.

Fig. 9. Rolling phase Clarion loam along the Little Sioux river.

The topography of the phase is indicated in the name. It varies however in different parts of the county from strongly rolling to rather steep in the less extensive areas adjacent to the streams, to only slightly more rolling than the typical soil, in the more extensive areas, farther away from the streams. The phase is well drained in all areas and in some cases where the subsoil is particularly sandy and gravelly, the drainage is excessive. Erosion is active and there is considerable washing of the surface soil particularly in the steeper areas.

Most of the land included with the rolling phase Clarion loam was originally prairie and only on narrow areas near lake shores and in river valleys are there found remnants of a forest growth. Probably two-thirds to three-fourths of the phase is in pasture and hay land. Wild hay predominates but the acreage in tame hay is increasing. In the more gently rolling areas, the soil is used for grain production. Corn, oats, barley and wheat are the crops grown. Corn averages 30 to 35 bushels per acre; oats, 30 to 35 bushels; barley, 20 to 25 bushels; and wheat, 10 to 12 bushels per acre. The chief hay crop is timothy and clover mixed. Some timothy is grown alone and occasionally clover is grown alone. There is a small acreage in alfalfa. The yield of tame hay averages from 1 to 2½ tons per acre. Excellent yields of alfalfa are secured.

This soil is chiefly in need of protection from erosion if it is to be made more highly productive. From among the methods described earlier in this report, one may be chosen which will serve under almost any condition and prevent the washing away of the surface soil and the formation of gullies. On the steeper slopes, the land should undoubtedly be left in pasture as the only means of preventing serious washing. On many areas, however, the land may be profitably cultivated, provided precautions are taken to

Fig. 10. Okoboji Lake, Dickinson county.

protect it from washing. When cultivated, the soil will respond to liberal applications of manure and this material will also aid in limiting washing, by making the soil better able to absorb the rainfall. The surface soil of the phase is acid and applications of lime are needed. The content of phosphorus is low and additions of phosphorus fertilizers would undoubtedly prove profitable for general farm crops. The chief need of the phase, however, is for organic matter and farm manure is recommended for liberal use. When this material is not available, then legumes should be turned under as green manures to increase the organic matter content of the soil.

WEBSTER SILT LOAM (113)

The Webster silt loam is the third largest soil type in the county, covering 10.5 percent of the total area. It occurs in numerous areas varying widely in size, in all parts of the county. It is most extensively developed in Milford, Lloyd and Richland townships. It occurs less extensively on the higher drift plains of Westport and Excelsior townships. It is also found on an isolated plain in Diamond Lake township. Numerous small areas occur in other parts of the county on gradual slopes and in level parts of the uplands. The largest area is located in Milford township extending into Lloyd township.

The surface soil of the Webster silt loam is a black silt loam, mellow to a depth of 8 inches and more plastic to 14 inches. The subsoil is a dark brownish-gray moderately plastic silty clay loam, which at the lower depths becomes heavily mottled with gray, rusty brown and yellow brown. Sand, pebbles and some boulders are found in the soil and in the subsoil but only in small quantities. The subsoil is calcareous and sometimes the subsurface soil is high in lime. The surface soil is only rarely calcareous. In a few areas

probably representing former lake terraces, the subsoil is a heavy, sandy, gravelly clay, and thin layers of sand and gravel occur at varying depths. On some of the slightly elevated portions of areas of the type, on the gentle slopes between the type and the soils of the Clarion series, and between these soils and the Lamoure soils along the drainageways, the surface soil approaches a loam in texture containing more sand than the typical soil. In some areas associated with the Webster silty clay loam, small areas of that type, too small to separate out on the map are included. The location of the boundary line between these two types is often arbitrarily placed, as there is a gradual gradation from the one soil to the other. Similarly the boundary between the Webster silt loam and the Clarion silt loam has also been placed rather arbitrarily in some cases.

In topography the Webster silt loam is level to gently undulating. The drainage of the soil is apt to be inadequate and the installation of tile is often necessary. On the more gently sloping areas, the drainage is better but the level areas, when drained, are usually too wet for the best growth of crops.

The greater part of the type is utilized for the production of general farm crops. Only in the still poorly drained areas, is the land used for pasture and for the production of wild hay. Corn is the most important crop grown, with oats second and hay third. Corn yields 40 to 55 bushels per acre; oats, 30 to 45 bushels; and hay 1½ to 2½ tons per acre. The tame hay usually consists of timothy and clover mixed. Some timothy is grown alone and yields 1½ to 2 tons per acre. Sometimes clover is grown alone and yields of 2 to 2½ tons per acre are secured. Alfalfa is grown successfully when the soil is well drained. Flax is commonly sown on newly broken areas of the type. Some rape, millet, sorghum and buckwheat are grown.

When adequate drainage is provided, the yields of crops on the Webster silt loam are usually quite satisfactory. Drainage is the first treatment needed. It will respond to applications of farm manure, however, as has been shown in the greenhouse experiments noted earlier in this report. It is not desirable to apply manure just preceding the small grain crop of the rotation, as it may cause the grain to lodge. When used at other points in the rotation, however, the effects on the other crops are quite beneficial. The surface soil of the type is usually acid in reaction and when this is the case, limestone should be applied if the best growth of legumes is to be secured. The soil is not very well supplied with phosphorus and the application of a phosphate fertilizer might often prove profitable. Tests on the individual farms are recommended.

CLARION SILT LOAM (169)

The Clarion silt loam is the fifth largest soil type in the county, covering 7.4 percent of the total area. It occurs most extensively in Westport and Okoboji townships. It is also an important type in Silver Lake and Diamond Lake townships, occurring in smaller areas. The largest area of the type is located in the central western sections of Okoboji township and extending into Westport township. Three other extensive areas occur in the latter township. Small areas of the soil are found scattered in other parts of the county.

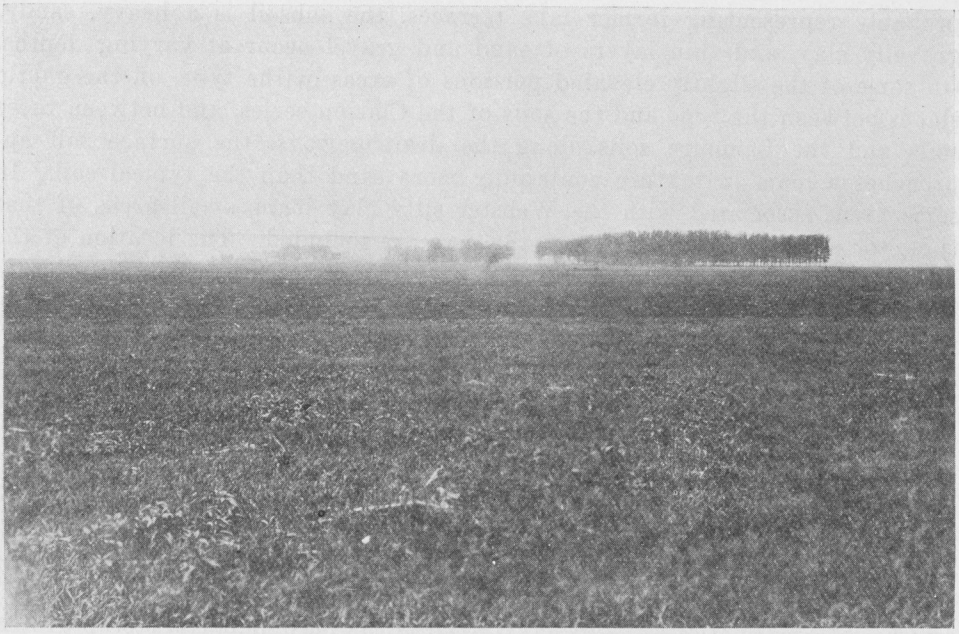


Fig. 11. Clarion silt loam topography.

The surface soil of the Clarion silt loam is a dark brown to almost black mellow silt loam, to a depth of 16 to 18 inches. There is a gradual change, to this point, to a lighter color and a heavier structure in the soil. The subsoil is a light brown to a grayish-brown silty clay loam. At the lower depths the gray color predominates. Sand and pebbles occur in the soil and subsoil but only in small quantities. The subsoil is highly calcareous and sometimes the subsurface soil is high in lime. The surface soil is usually quite acid in reaction.

In topography the Clarion silt loam is level to gently rolling. The areas in Okoboji township are nearly level. Those in Westport township, southwest of Stony creek are quite rolling. The drainage of the soil is generally inadequate and the installation of tile is needed for the best crop production. The surface drainage is better in the more rolling areas but the heavy texture of the subsoil makes the internal drainage poor. The level areas in Okoboji and Western Milford townships often have thin layers of sand and gravel under the subsoil, or below the 3 foot section and this permits of better drainage. But in general tiling is very desirable on this soil.

All of the Clarion silt loam is under cultivation and general farm crops are grown. Corn is the most important crop, followed in order by oats, hay, barley and wheat. Corn yields 45 to 55 bushels per acre; oats, 30 to 50 bushels; clover and timothy mixed, 2 to 2½ tons; clover alone, 2½ tons; barley, 25 to 35 bushels; and wheat, 20 to 25 bushels per acre.

The Clarion silt loam is naturally a productive soil and crop yields are usually quite satisfactory. As has been indicated, however, the soil must be thoroly drained before the best crops will be secured. Tiling is recommended

on all areas which are still too wet. The soil will respond to applications of farm manure and liberal amounts should be used. If manure is not available then legumes should be used in order to supply organic matter and nitrogen. The soil is acid in the surface and the application of limestone will be needed if legumes are to be grown. It is very desirable to test this soil before growing a legume, and to apply lime as needed. The soil will probably respond profitably to applications of phosphorus fertilizers, for it is not high in phosphorus. It is urged that farmers test the value of acid phosphate and rock phosphate on their own soils, by carrying out tests on small areas.

CARRINGTON LOAM (1)

The Carrington loam is the sixth largest soil type in the county, covering 5.8 percent of the total area. It occurs mainly near the main drainageways in the morainic region. There are, however, small isolated areas, not associated with the drainageways. The areas in sections 8, 9, 10, and 11 of Milford township are typical of these isolated areas. The type is found most extensively in Spirit Lake, Center Grove, and Diamond Lake townships. There are other areas, however, in all parts of the county, particularly along the Little Sioux river. The largest individual areas are located in the vicinity of Spirit Lake.

The surface soil of the Carrington loam is a dark brown to almost black loam to a depth of 10 to 12 inches. Below that point the soil is a brown to dark brown silt loam, to a depth of 16 to 18 inches. The subsoil is a compact, friable, light yellowish-brown silty clay loam. The surface soil varies in different areas to a heavy fine sandy loam or a light silt loam. In the more rolling areas there is apt to be more variation in texture. Sand and gravel occur in varying amounts, sometimes giving the lower subsoil a light silty clay loam texture. Thin layers of loose sand and gravel are occasionally found in the subsoil. In some places these layers are composed of a uniform fine sand. Boulders occur thruout the soil and subsoil and are occasionally exposed on the surface. Included with the type there are small areas of a fine sandy loam which are too small to separate on the map.

In topography the Carrington loam is gently rolling to rolling. The areas in Milford township are less rolling, occupying broad elevations and gentle slopes. In sections 3 and 10 of Okoboji township, the type is quite level, lying between the Little Sioux river bluffs and the gravelly terrace to the east. The soil is generally very well drained. Where the soil is more sandy, the drainage is better. On the areas, where the subsoil is heavier, and on the more level areas, drainage is not so complete. The use of tile is rarely needed, however.

Some areas of the soil were originally forested, and there are still remnants of woodlands near lake shores and river valleys. Bur oak, elm, and box elder are the most common trees. At the present time more than half of the type is in hay and pasture and the remainder is in grain crops. It is all utilized agriculturally, the wooded areas serving for pasture. Corn, oats, barley and wheat are the main crops grown. Tame hay is produced in much greater amount than wild hay. The yields of crops are very much the same as on the Clarion loam, and the needs of the soil are very similar.

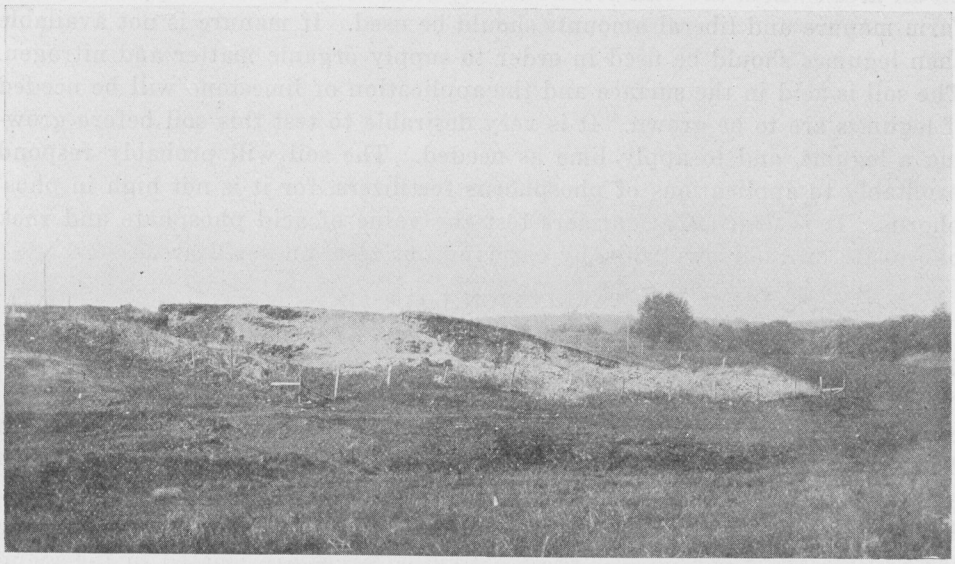


Fig. 12. Gravel pit in Pierce fine sandy loam.

Crop yields may be increased on the Carrington loam by proper methods of soil treatment. Applications of farm manure are particularly desirable. The beneficial effects of this material have been shown by greenhouse and field tests described earlier in this report and have been confirmed by much farm experience. When farm manure is not available for use then it would probably often be desirable to turn under leguminous crops as green manures in order to increase the content of organic matter and nitrogen and to keep the soil permanently productive. The type is acid in reaction and the addition of lime is necessary if legumes are to be grown. The soil should be tested. Often all the crops grown will be benefited by the use of lime. The soil is not well supplied with phosphorus and additions of phosphorus fertilizers may be very desirable in many cases at the present time. The experiments along this line are not conclusive but they indicate that profitable returns may often be secured from the use of a phosphate. Tests of rock phosphate and of acid phosphate on the farm are recommended.

PIERCE FINE SANDY LOAM (170)

The Pierce fine sandy loam is the seventh largest soil type in the county, covering 4.2 percent of the total area. It occurs mainly in the rolling morainic regions near the lakes or former lake beds and adjacent to the streams. It is developed chiefly in Lakeville township and in the northern part of Milford township. There is also considerable occurrence of the type in Superior township and in Center Grove and Spirit Lake townships. There are small areas of the type in other parts of the county, but they are of minor importance. The largest areas of the soil are found in Lakeville, Milford and Superior townships. The most extensive individual area is located in Lakeville township just west of West Okoboji lake.

The surface soil of the Pierce fine sandy loam is a dark brown fine sandy loam, extending to a depth of 10 inches. The subsurface soil, from 10 to 18 inches, is a brown to dark yellowish-brown loam to clay loam or clay. There is usually sufficient coarse sand and gravel in the subsurface soil to give a texture varying from a loose sandy clay loam to a moderately heavy sandy clay loam to sandy clay. The heavier material generally occurs only in thin layers. Below 18 inches, the subsoil is a loose sand and gravel containing varying amounts of silt and clay. Boulders occur thruout the soil and subsoil and are often exposed on the more rolling slopes and on the narrow ridges. The subsoil is highly calcareous and sometimes the subsurface soil is also high in lime. Within the type there are included small areas of the Clarion fine sandy loam and of the rolling phase Clarion loam, and in some places the boundaries have been rather arbitrarily located.

In topography the Pierce fine sandy loam is rolling to steeply rolling. Isolated kames or knolls occur frequently thruout the type. In section 19 of Spirit Lake township, there is found the most typical of these kame formations. In this area the kame rises 50 feet above the surrounding land. Usually the kames are about 20 feet above the adjacent country and on all of them the slopes are eroded and covered with boulders. The many small oval shaped areas of the type shown on the map are in the form of kames. In the larger areas of the type, the occurrence of the kames is not so noticeable. In some areas the type occurs as ridges surrounding former lake beds or small lakes and shutting them off from natural drainage outlets. The area around Sunken lake in section 17 of Spirit Lake township is an example of this topographic occurrence of the type. The soil is generally thoroly to excessively drained. Where the underlying gravel and sand layer is thin the water holding power of the soil is greater, but in most areas, the type is apt to be droughty.

A large part of the type in the vicinity of lakes and streams was originally in forest and remnants of second growth forest still exist. Bur oak, red oak, elm, box elder, haw, crab apple, and basswood are found in these woodlands. About 40 percent of the soil is now in grain crops and the remainder is utilized for hay and pasture. Corn is the most important crop yielding 25 to 35 bushels per acre. Oats is second, yielding 25 to 30 bushels per acre. Barley and wheat are of minor importance, the former yielding 15 to 25 bushels and the latter 10 to 20 bushels per acre. Average yields of hay amount to three-fourths of a ton to 1½ tons per acre. The hay crop usually consists of clover and timothy mixed. Some clover is grown alone and alfalfa is also sometimes grown. Rye is occasionally used as a cover crop on slopes subject to erosion. The areas of the type on the kames are seldom cropped and when they are, they are used for hay.

This soil is chiefly in need of additions of organic matter to increase its water holding power and lessen the danger of crop injury from drought. The increase in organic matter will also bring about less erosion and washing away of the soil. The fertility of the land will be increased and crop yields will be very largely increased, from additions of farm manure. Liberal applications of this material are very desirable where the soil is used for

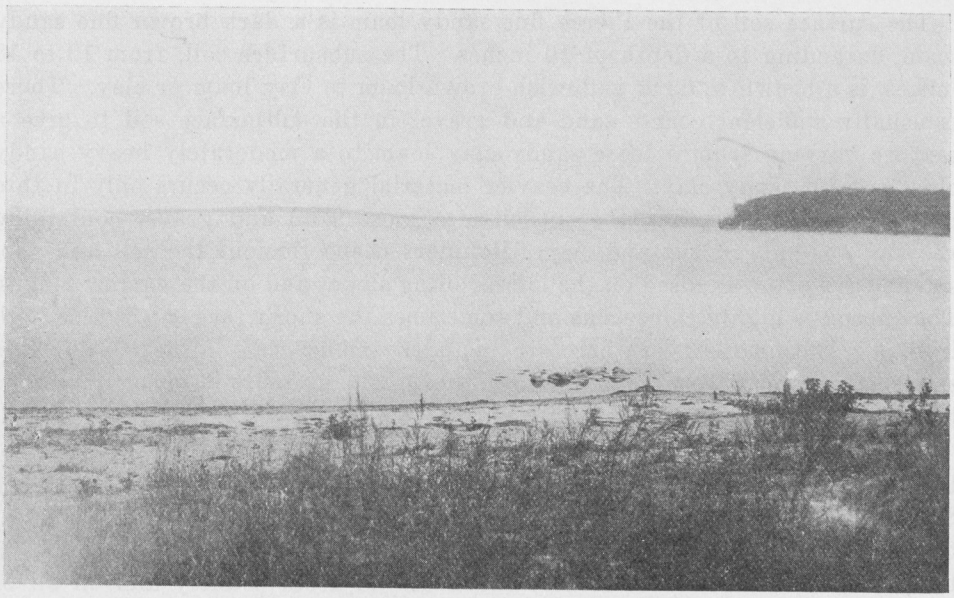


Fig. 13. West Okoboji Lake.

cultivated crops. If farm manure is not available for use, then leguminous crops should be used as green manures. The surface soil is acid in reaction and additions of lime would be of value in increasing the growth of legumes. The phosphorus content is low and the application of a phosphate fertilizer would probably prove of value. Tests of rock phosphate and acid phosphate on the farm are recommended. In the rougher, steeper areas, the soil should undoubtedly be left in pasture but on the more level areas it may be cultivated and by following the methods of treatment suggested, good crop yields may be secured. Protection from erosion is always necessary and some one of the methods suggested earlier may be utilized to prevent serious washing of the soil.

PIERCE LOAM (173)

The Pierce loam is a minor type in the county, covering 2.4 percent of the total area. It occurs in numerous areas in all parts of the county. Most of the areas are very small in size. The largest individual areas are found in sections 4 and 9 of Okoboji township and in sections 21 and 22 of Center Grove township. The largest development of the type is in Center Grove township, where numerous areas occur. It is found in association with the fine sandy loam, with the rolling phase Clarion loam and with the typical Clarion loam, and the areas are generally small and irregular in shape, sometimes, long and narrow and often oval where they occur in knolls or kames.

The surface soil of the Pierce loam is a dark brown to black compact loam to a depth of 10 inches. The subsurface soil, from 10 to 18 inches, is a light brown to yellowish-brown, coarse, sandy to moderately heavy gravelly loam. In places the soil at this depth is rather compact but such compact layers are

thin and inextensive. The subsoil is a loose sand and gravel, containing some silt and clay. The texture of the subsoil varies from a light coarse sandy clay loam to a loose porous sand or coarse sand. Boulders are present in the soil and on the surface. They are most numerous on the kames and in the eroded areas. The subsoil is usually moderately to highly calcareous. The boundary lines between this type and the fine sandy loam are often difficult to draw and they are rather arbitrarily established in some cases.

In topography the Pierce loam is moderately rolling to rolling. The type is usually not quite so rolling as the Pierce fine sandy loam but the kame areas are quite steeply rolling. In the areas in sections 9 and 10 of Excelsior township, the topography is rather steep and the slopes of the kames have been eroded extensively, in some cases exposing the boulder clay underlying the gravel and sand. The soil is excessively drained and is droughty.

The greater part of the type is a prairie soil. Some of the areas, however, are in forest growth. The soil is utilized for pasture in the rougher and kame areas but the more gently rolling areas are cultivated. The crops grown are the same as those grown on the fine sandy loam, and the yields are very much the same.

The needs of this soil for the best crop growth on the cultivated areas are similar to those of the Pierce fine sandy loam. Applications of organic matter are very necessary. Liberal additions of farm manure should be made and if farm manure is not available in sufficient amounts then leguminous crops should be used as green manures. The surface soil is acid and should be limed before legumes are grown. The content of phosphorus is low and additions of phosphorus fertilizers would undoubtedly prove beneficial. Tests of acid phosphate and rock phosphate are very desirable. The soil must be protected from erosion and some one of the methods suggested earlier in this report may be used to combat this destructive action successfully.

WEBSTER SILTY CLAY LOAM (107)

The Webster silty clay loam is a minor type in the county, covering 1.7 percent of the total area. It occurs in numerous small areas in all parts of the county. The largest development of the type is in Milford, Lloyd and Richland townships. Areas in other parts of the county are small and relatively unimportant.

The surface soil of the Webster silty clay loam is a black silty clay loam to a depth of 16 to 18 inches. The soil is moderately friable when dry but it is plastic when wet. The subsoil is a dark brownish-gray plastic silty clay loam to silty clay, passing at 30 inches into a lighter brownish-gray silty clay loam or silty clay, heavily mottled with light gray, yellow and brown. The subsoil is usually highly calcareous and occasionally lime occurs in the upper soil layers but only in small amounts. Sand and pebbles occur thruout the soil in small quantities. In depressions where the land was formerly swampy, there is a thin layer of muck over the surface soil. In a few places the subsoil contains enough sand and gravel to make it a heavy sandy gravelly clay or sandy clay loam in texture. Such a subsoil condition occurs in the areas in section 3 of Richland township and in section 33 of Superior township.

In topography the type is level to depressed. It usually occurs in the lowest upland depressions, being found in former lake beds, former swampy or ponded areas or in poorly drained areas at the head of upland drainageways. In some areas it occurs between the higher lying Clarion loam and the lower level areas of Webster silt loam. The area in section 26 of Richland township is in this position. The areas in Diamond Lake township occur on a level depressed drift plain. The typical level topographic position and the heavy texture of the soil and subsoil make this soil poorly drained, and in many cases it is too wet for the best crop growth.

About one-third of the type is now sufficiently drained to permit of cultivation. The remainder is in pasture and in wild hay land. Corn is the chief crop grown on the cultivated areas and yields range from 40 to 55 bushels per acre. Some oats are grown and yield 30 to 40 bushels per acre. Clover and timothy mixed yield 2 to 2½ tons per acre. Clover alone yields 2¼ to 2½ tons and timothy alone, 1½ to 1¾ tons per acre. The yield of wild hay amounts to 1½ to 1¾ tons per acre.

The Webster silty clay loam is naturally a very rich soil. When it is well drained, which is the first requisite for good crop growth, the yields of ordinary farm crops are very satisfactory. Small applications of farm manure are of value on the soil but this material should not be applied immediately preceding the small grain crop of the rotation as it may cause the grain to lodge. When applied at other places in the rotation, however, crop increases are commonly secured. The use of manure is particularly desirable on newly drained areas, as it brings about a stimulation of bacterial action and a better production of available plant food. When the surface soil is acid the application of lime might prove of value for the best growth of legumes. The addition of a phosphate fertilizer might prove profitable and tests of rock phosphate and acid phosphate on the farm are recommended.

In some areas of the type there are narrow strips on the edges of former swamps and ponds, where there is an accumulation of so-called alkali salts. These areas are characterized by the appearance of a whitish deposit on the surface of the soil and crop growth is considerably reduced. For the reclamation of such spots, drainage is first needed, and then a liberal application of horse manure. The turning under of a green crop also aids in removing the excess of salts. These so-called alkali spots are small in area and of only local importance. The salts present are very different than the alkali salts in western soils and the reclamation of the spots is quite readily accomplished.

CARRINGTON SILT LOAM (83)

The Carrington silt loam is a minor type in the county, covering 0.9 percent of the total area. It occurs in many small areas thruout the county, but chiefly in the northern townships. The most extensive development of the type is in the northern part of Silver Lake township. The largest areas of the soil are located in the extreme northwestern part of this township and in the northern and central part of Spirit Lake township. In places it occurs on the slopes between the Webster and Carrington soils. In other areas it is found on the nearly level hilltops.

The surface soil of the Carrington silt loam is a dark brown to almost black silt loam to a depth of 14 or 16 inches. There is a gradual change beginning at 16 to 18 inches into the light brown to yellowish-brown silty clay loam subsoil. The subsoil is compact and friable and slightly heavier below 20 inches. In the areas in sections 8, 10 and 11 in Spirit Lake township, north of the lake, the surface soil is 12 inches in depth, changing at that point into a brown to dark brown silty clay loam which at 20 inches becomes a dull yellowish-brown, faintly mottled with rusty brown. At 24 inches the gray and rusty brown mottlings are abundant. The boundary lines between the type and the Carrington loam are often difficult to locate owing to a gradual change from one soil to the other, and they are sometimes placed rather arbitrarily.

In topography the Carrington silt loam is gently rolling. In some areas it is more level, where it occurs on the broad hilltops. The soil is usually well drained but in some cases the installation of tile would be desirable. The more level areas and those associated with the Webster soils are more apt to be in need of drainage.

The type was originally a prairie soil with little or no forest growth. About 70 to 80 percent of the soil is in grain crops and the remainder is in hay or pasture. Corn is the leading crop grown and yields of 40 bushels per acre are secured on the average. Oats yields 35 to 40 bushels. Wheat is sometimes grown and good yields are obtained. The yield of hay on the type is excellent.

While the Carrington silt loam is naturally a productive soil it may be made to yield greater crops by the application of certain fertilizers. The addition of liberal amounts of farm manure will bring about large crop increases. The soil is acid and lime should be applied if crop growth is to be most satisfactory, particularly in the case of legumes. The phosphorus content of the soil is not high. Tests of acid phosphate and rock phosphate on the farm are very desirable. Indications have been secured pointing to the possibility of value from the use of one or the other of these materials.

CLARION FINE SANDY LOAM (149)

The Clarion fine sandy loam is a minor type in the county, covering 0.9 percent of the total area. It occurs mainly in Lakeville township between the Little Sioux river and West Okoboij lake, and in Superior township east of Swan lake. The largest areas are found in sections 10, 15 and 22 of Lakeville township. Small areas are present in other parts of the county but they are of minor importance.

The surface soil of the Clarion fine sandy loam is a brown to dark brown fine sandy loam to a depth of 10 inches. At that point it passes into a lighter brown to yellowish-brown heavy compact silt loam to silty clay loam. At 18 inches, the soil is a light yellow or grayish-brown friable silty clay loam. Usually at a depth of 24 to 28 inches, the subsoil is distinctly gray in color and there is a high content of lime. At the lower depths there is an increasing content of sand and gravel and the subsoil approaches a heavy sandy clay loam in texture. Boulders occur thruout the soil and often on the surface.

In topography, the type is usually gently rolling to rolling. The areas in section 15 of Milford township and in section 21 of Center Grove township

show the typical rolling topography. The area east of Swan lake in Superior township is the most rolling of any areas of the type. There the soil is cut into ridges with narrow crests and sharp slopes, which are often steep and eroded. Similar ridges occur in the type, where it is found in the small areas in the morainic region. The large area in Lakeville township shows a more irregular, hillocky topography. The soil is naturally well drained but it is not droughty like the Pierce soils with which it is often associated.

Practically all of the Clarion fine sandy loam is utilized agriculturally, about 50 to 60 percent being in grain crops and the remainder in hay and pasture. There is only a very small area in forest growth and this land is used for pasture. Corn is the chief crop grown but small grains and hay are also grown to a considerable extent. The yields of crops are somewhat lower than those secured on the Clarion loam but they are higher than those on the Pierce soils.

This soil can be made more productive by proper treatment. It will respond to liberal applications of farm manure, and this material should be used in as large amounts as available. The type is acid in reaction and applications of lime are necessary if the best crop growth, particularly of legumes is to be secured. The addition of a phosphate fertilizer would probably prove profitable and tests of acid phosphate or rock phosphate are recommended.

DICKINSON LOAM (174)

The Dickinson loam is a minor type in the county, covering 0.7 percent of the total area. It is developed mainly in Westport township. The largest area is found in sections 31 and 32 in the extreme southwestern corner of the county. Small areas occur in other parts of Westport township and in Lakeville township.

The surface soil of the Dickinson loam is a dark brown loam to a depth of 14 inches. Below that point it becomes a light brown to brown heavy sandy loam to light loam and at 20 to 24 inches the subsoil, a light brown loose fine sand or sand, is encountered. In an area in section 10 of Milford township and in another in section 33 and 34 of Lakeville township, the subsoil beginning at a depth of 14 to 24 inches is a brown to dark brown brittle silty clay loam and the loose sand does not occur above 32 inches. The area in section 26 of Westport township has pockets of coarse sand and gravel thru the subsoil. Boulders occur thruout the soil and often on the surface. The area in section 26 of Westport township shows the largest number of boulders. In some cases as in the areas in Lakeville township, the boundary lines are rather arbitrarily placed, as there is a gradual change from the Dickinson loam into the adjoining types which have heavier subsoils.

In topography the type is typically gently rolling but there are some level to gently rolling undulating areas. Where the type occurs on the slopes adjacent to the valley of Stony creek, the topography is often more strongly rolling. The soil is well drained and in periods of light rainfall, it is apt to be excessively drained and may be droughty. In the areas in Milford and Lakeville townships and in the small areas in Westport township where the subsoil is a heavier silty clay loam, the water holding capacity of the soil is greater and the crops are not so apt to suffer in dry seasons.

The Dickinson loam is all utilized agriculturally. About 60 percent is in grain crops and the remainder is in hay and pasture. Corn is the chief crop grown but there is also a large production of oats. The yields are somewhat lower than those secured on the Clarion loam but in favorable seasons, good yields are secured.

Large crop increases are always obtained, when manure is applied. If farm manure is not available for use, then legumes should be used as green manures, in order to build up the content of organic matter and nitrogen and keep the soil better supplied with moisture. The soil is acid and applications of lime are necessary if the best growth of legumes is to be secured. Other crops are often benefited by the use of lime on this soil. The content of phosphorus is not high and additions of phosphorus fertilizers may bring about large crop increases. It is recommended that rock phosphate and acid phosphate be tested on small areas on individual farms in order to learn whether or not phosphorus fertilizers are needed on the soil and which one should be employed.

DICKINSON FINE SANDY LOAM (175)

The Dickinson fine sandy loam is a minor type in the county, covering 0.4 percent of the total area. It occurs mainly in Westport township in association with the Dickinson loam. A rather extensive area is found in Lakeville township in sections 11 and 14. Several small areas occur in southeastern Okoboji and southwestern Milford townships.

The surface soil of the Dickinson fine sandy loam is a dark brown fine sandy loam to a depth of 10 inches. Below this point to a depth of 18 inches, the soil is a light brown to dark brown somewhat more compact loam. The subsoil is a loose porous sand to sandy loam, generally containing some coarse sand and gravel. In some areas the subsurface layer of heavier loam is thinner and in places, it is absent. Gravel and coarse sand occur more commonly throut the soil than is true of the Dickinson loam and there are more boulders present.

In topography the type is rolling. In the areas adjacent to streams and in the higher lying areas the surface is more strongly rolling and erosion often occurs to a considerable extent on the rather steep slopes. The soil is excessively drained and is apt to be droughty.

About two-fifths of the Dickinson fine sandy loam is utilized for grain crops and the remainder is in pasture and hay. Crop yields are lower than those secured on the loam. The soil is chiefly in need of organic matter to make it more productive. Liberal applications of farm manure are recommended for use and large crop increases will always be secured from the use of this material. When farm manure is not available for use in sufficient amounts, then legumes should be used as green manures to increase the supply of organic matter in the soil. The soil is apt to be droughty and when the amount of organic matter is increased, there will be less danger of injury to crops in dry seasons. The soil is acid and additions of lime are necessary for the best growth of legumes. The phosphorus supply is not high and additions of phosphorus fertilizers would probably prove of value.

TERRACE SOILS

There are five terrace soils in the county, classified in the O'Neill, Sioux and Fargo series. Together they cover 5.6 percent of the total area of the county.

O'NEILL LOAM (108)

The O'Neill loam is the largest of the terrace soils, covering 3.6 percent of the total area of the county. The most extensive area of the type is in Okoboji township east of the Little Sioux river. This terrace, locally known as the Milford terrace covers an area of about 10 square miles. Other areas, small in extent occur along the Little Sioux river and in other parts of the county along the streams, lakes and former lake beds. A few small isolated areas are found in the uplands entirely separated from the drainageways. These areas were evidently formed at some earlier geological period by the glaciers.

The surface soil of the O'Neill loam is a dark brown to black moderately compact loam, about 12 inches in depth. The subsurface soil to a depth of 18 to 20 inches is a dark brown mellow silt loam containing some coarse sand and gravel. The subsoil is a coarse sandy loam to coarse sand and gravel containing little clay and silt. In the south half of sections 25 and 26 of Okoboji township and in some small areas in other parts of the county, the surface loam is deeper and more compact and the subsurface heavy silt loam extends to a depth of 24 to 26 inches, at that point resting upon the loose coarse sandy loam subsoil. In some places the heavier silt loam subsurface layer is absent and the surface loam rests directly upon the loose coarse sandy loam to gravelly loam subsoil. Spots in sections 1, 2, 3, 11, 12, and 13 of Okoboji township and in sections 6 and 7 of Milford township, near the streams and drainageways show this soil profile. The large gravel pits in the county are found in such areas. The chief of these is the railroad pit south of Milford.

The O'Neill loam occupies flat terraces usually 50 feet or more above the first bottoms. In some places it is lower, being only 15 to 20 feet above the bottomland. The topography of the type is level. Drainage is excessive owing to the loose character of the subsoil, and the type is droughty. The areas having the heavier silt loam subsurface layer are less droughty.

About 70 percent of the type is utilized for the growth of grain crops and the remainder is in pasture and hay land. Corn yields about 30 bushels per acre; oats, 25 to 30 bushels; barley, 20 bushels; wheat, 15 to 20 bushels; and clover and timothy mixed, 1 to 1¼ tons per acre. The yields of crops vary widely depending upon seasonal conditions. If the season is dry, the yields will be very poor and in good seasons, high yields are often secured.

The O'Neill loam needs organic matter chiefly, in order to make it more productive and to lessen the injury to crops from drought. Liberal amounts of farm manure should be applied and large increases in crop yields may be secured thru the use of this material. Leguminous crops should be used as green manures to supplement the farm manure or as a substitute for that material. By the use of farm manure and green manures the organic matter content of the soil may be increased and crop growth will be more certain to be satis-

factory. The soil is acid in reaction and applications of lime are needed. All crops will be benefited by the use of lime and legumes will be increased to a very large extent. The content of phosphorus in the soil is not high and it seems quite probable that additions of phosphorus fertilizers might be of large value. Tests of acid phosphate and rock phosphate on small areas on individual farms are recommended.

SIOUX LOAM (76)

The Sioux loam is a minor type in the county, covering 1.0 percent of the total area. The type occurs mainly in Westport township along Stony creek. The largest area is found in sections 6 and 8 of Westport township. Small areas are located in Excelsior township and in other parts of the county on low terraces along the streams.

The surface soil of the Sioux loam is a dark brown loam to a depth of about 14 inches. It is moderately compact at the surface, gradually changing to a coarser loam. The subsoil is a loose sand and gravel, containing small amounts of silt and clay. The subsoil is calcareous. In section 12 of Silver Lake townhip, the surface soil is a coarse loam approaching a coarse sandy loam. This coarser surface soil also occurs in other areas bordering on the first bottoms. In section 16 of Westport township, the soil consist of a light silt loam, underlaid at varying depths by sand and gravel. In other areas where the soil is associated with the Fargo soils this same variation from the typical soil occurs. In some areas adjacent to muck beds, the surface soil has a somewhat mucky structure.

The Sioux loam occurs on level terraces, usually only 5 to 10 feet above the bottomland or lake beds. Occasionally the areas are 15 to 20 feet above the bottoms. In topography, the type is level. Drainage is excessive due to the loose gravelly character of the subsoil. The soil is apt to be droughty and crops may suffer in dry seasons.

About three-fifths of the soil is utilized for grain crops, the remainder being in pasture or hay land. Corn and small grains are about equal in acreage. The yields of these crops are somewhat lower than on the O'Neill loam. Over half of the hay is wild hay but the area in tame hay is increasing. Yields of tame hay amount to about 1½ tons per acre. Wild hay yields about 1 ton per acre.

This soil is especially in need of organic matter, like the O'Neill loam, in order to make it more productive. Liberal applications of farm manure should be made and leguminous crops should be used as green manures in order to increase the supply of organic matter and make the soil less droughty. The surface soil is acid and applications of lime are needed if legumes are to be most successfully grown. The content of phosphorus is not high and the use of a phosphate fertilizer would probably prove profitable. Tests on the farm of the value of a phosphate are desirable.

FARGO SILT LOAM (152)

The Fargo silt loam is a minor type in the county, covering 0.5 percent of the total area. It occurs in several small areas, the largest being located in Westport township, along Stony creek. Three areas occur in section 23

of Excelsior township and there are three small areas along Muddy creek in section 4 of Lloyd township and sections 33 and 34 of Richland township.

The surface soil of the Fargo silt loam is a black heavy silt loam to a depth of 10 inches. The subsoil is a black to dark brownish-gray silty clay loam, gradually changing into a light to dark brownish-gray plastic silty clay. The lower subsoil is mottled with yellow, gray and rusty brown. Where the type is associated with the terrace soils having sandy subsoils, there is often a thin layer of fine sand or coarse sand and gravel at 18 to 20 inches. The subsoil is highly calcareous and frequently the surface soil is also calcareous.

The Fargo silt loam is located on low level terraces, averaging about 10 feet above the bottomland. Some areas are lower and are occasionally overflowed. Others are 20 feet above the adjacent bottoms. Drainage of the soil is poor and tiling is necessary if it is to be made most satisfactorily productive.

About half of the type is utilized for the growth of grain crops and the remainder is in hay and pasture land. Corn is the chief crop, yielding from 20 to 50 bushels per acre. Oats yield from 20 to 40 bushels per acre. Tame hay yields from 1 to 2½ tons and wild hay from 1 to 1¾ tons per acre.

The type is particularly in need of drainage if it is to give the best yields. Tiling should be practiced wherever the land is still too wet. Small applications of farm manure would prove of value, especially immediately following the tiling out of an area. The soil would probably respond to applications of phosphorus fertilizers and tests of acid phosphate are recommended.

O'NEILL FINE SANDY LOAM (110)

The O'Neill fine sandy loam is a minor type in the county, covering 0.3 percent of the total area. It occurs in numerous small areas along the little Sioux river in Lakeville and Okoboji townships. Occasionally it occurs as elevated spots in areas of the O'Neill loam. The area just north of Milford is found in this position. Usually the type is found on the bluffs of the O'Neill loam terraces adjacent to the river valley.

The surface soil of the O'Neill fine sandy loam is a dark brown fine sandy loam to a depth of 10 inches. The subsoil is a variable, coarse textured sandy gravelly loam, containing a small amount of silt and clay. In the area in section 1 of Milford township, the surface soil is deeper, extending to a depth of 14 to 16 inches. Along the larger lakes there are areas of fine sand which owing to their small extent are included with this type. The material in these areas is a light yellowish-brown fine to coarse sand thruout the 3 foot section.

The type is level to gently sloping in topography and the drainage is excessive. The soil is usually quite droughty. A small part of it is utilized for tame grasses but most of it is kept in permanent pasture. Where the surface is deeper as in the area north of Milford, grain cropping is practicable. The type needs organic matter to lessen its droughtiness and liberal applications of farm manure should be made. Legumes should be turned under as green manures, to build up the supply of organic matter. The type is acid in reaction and applications of lime are necessary if legumes are to be successfully

grown. Phosphorus fertilizers would probably prove of value. If the soil is to be utilized for general farm crops, the treatments suggested, and particularly the additions of farm manure and green manures are very necessary.

FARGO SILTY CLAY LOAM (109)

The Fargo silty clay loam is a minor type in the county, covering 0.2 percent of the total area. It occurs in several small areas in various parts of the county. The largest areas are found near Hottes and Grovers lake in Spirit Lake and Diamond Lake townships and along Stony creek in Westport township. The areas vary from 10 to 120 acres in size.

The surface soil of the Fargo silty clay loam is a nearly black silty clay loam to a depth of 16 inches. The subsoil is a dark brownish-gray plastic silty clay to a depth of 24 inches and below that point, a light brownish-gray clay mottled with yellow, gray, and rusty brown. The subsoil is highly calcareous and often the surface soil is also high in lime.

The larger part of the type is used for hay and pasture, only about one-fourth of it being in grain crops. The wild hay consists largely of slough grasses. Yields amount to 1½ to 1¾ tons per acre. Clover and timothy make up the larger part of the tame hay grown. Yields of tame hay, corn and small grains are about the same as on the Fargo silt loam.

The Fargo silty clay loam is poorly drained naturally and the installation of tile is very necessary if the land is to be used for cultivated crops. Small applications of farm manure would be of value on newly drained areas. This material should not be applied just preceding the growing of a small grain crop. Additions of phosphorus might prove of value and tests of phosphorus fertilizers are recommended.

SWAMP AND BOTTOMLAND SOILS

There are two bottomland soils in the county, classified in the Lamoure and Wabash series and these together with the area of muck make three areas of swamp and bottomland soils. The total area covered by these soils amounts to 19.1 percent of the area of the county.

LAMOURE SILTY CLAY LOAM (111)

The Lamoure silty clay loam is the largest of the bottomland soils and the second largest soil type in the county, covering 15.8 percent of the total area. It occurs in all parts of the county, occupying all the upland drainageways and many of the depressions and practically all the larger stream bottoms in the county. Along Little Sioux river, except in Lakeville and Okoboji townships, and along Muddy creek and Stony creek the bottoms of this soil are not more than one-fourth of a mile in width. The largest and widest bottom area is found at the union of the two forks of the Little Sioux river. The most extensive areas of the type, however, are found in former lake beds. The largest single area in sections 23 and 26 of Excelsior township.

The surface soil of the Lamoure silty clay loam is a black silty clay loam to a depth of 10 inches. It is moderately friable when dry and rather plastic when wet. From 10 inches to 18 inches, the soil is somewhat lighter in color and more plastic. The subsoil below 18 inches is brownish-gray to dark gray

silty clay loam to silty clay, and below 24 inches it is a lighter brownish-gray silty clay, mottled with yellow, gray, and rusty brown. The subsoil is high in lime and often the surface soil is also calcareous.

In some places, the subsoil grades into a light grayish or yellowish-brown, sandy clay, rather coarse in texture, at depths of 20 inches. This variation from the typical soil usually occurs in areas occupying former ponds or swamps. In other areas, the subsoil, at the lower depths is a dark brownish-gray to black silty clay practically free from mottling. Variations are common in the surface soil of the type. In areas adjacent to muck beds, there is a surface layer of muck, 1 to 4 inches in thickness in some places. In the narrow depressions in the uplands, the surface material is made up largely of wash from the surrounding territory and varies from a loam to silt loam in texture. These areas are so small that they cannot be shown on the map. Similar areas where the surface soil is lighter in texture than the typical silty clay loam, are found in some of the bottoms along the larger streams. In some cases there is a gradual change from the silty clay loam texture nearer the stream channels thru a silt loam to a loamy texture further away from the streams.

In topography, the Lamoure silty clay loam is nearly level to very slightly sloping. In areas permanently saturated, the surface often has a hummocky appearance. The soil is naturally poorly drained and much of the type is too wet for crop growth. It is all subject to overflow.

Only a very small proportion of the type is cultivated. Most of it is utilized for hay and pasture. Slough grasses grow luxuriantly in the narrow swales, small stream bottoms and former swamp and lake beds. They are pastured in most cases but occasionally they are cut for hay. On cultivated areas, general farm crops are grown. Corn yields 45 to 55 bushels per acre. Small grains give lower yields proportionately. Clover and timothy, the chief tame hay crop, yield 2 to 2½ tons per acre. Wild hay yields 1½ tons per acre.

Thoro drainage is the first treatment needed to make the Lamoure silty clay loam suitable for cultivated crops. It should be pastured, or cropped to hay, flax, potatoes or some short season crop for several seasons. Then it may be utilized for general farm crops, and very satisfactory yields may be secured. Small applications of farm manure will prove of value on newly drained soils. This material should not be applied preceding the small grain crop, however, as it may cause the crop to lodge. Phosphorus fertilizers might prove of value and tests are recommended, using acid phosphate on a small area, and comparing the yield secured with that obtained on a corresponding untreated area. Occasionally small strips of so-called alkali spots occur in this type and these areas may be reclaimed by thoro drainage and by the introduction of liberal amounts of horse manure or the turning under of a green crop. Much of the land in this type should undoubtedly be kept in permanent pasture.

MUCK (21a)

There is considerable muck in the county, amounting to three percent of the total area. It occurs in numerous areas in all parts of the county in former swamps and lake beds. Small areas are also found in the bottoms of the

Fig. 14. Muck area on old Swan Lake bed. Adjacent hills are Clarion loam.

Little Sioux river. The areas vary widely in size, ranging from a few acres to about 200 acres. The largest areas occur in sections 18 to 19 of Silver Lake township, in sections 30 to 31 of Lakeville township in the area which was formerly Sylvan lake and in Superior township, where Swan lake formerly was located.

The surface material of muck is a partly decomposed mixture of former swamp and lake bed vegetation, mixed with varying amounts of silt and clay and some sand washed from the adjacent slopes. It extends to a depth of 16 inches, on the average. The subsoil is a black plastic silty clay loam usually changing to a dark to light brownish-gray silty clay in the lower subsoil. The subsoil is highly calcareous. In some areas about two inches of peaty material is found on the surface. In others this peaty material may extend to a depth of 10 to 12 inches. These areas are too small to show on the map and they are included with the muck. In spots, the subsoil consists of a coarse sand and gravel. The areas in sections 19 and 20 show this subsoil condition. Two areas of peat occur in the county, one in sections 24 and 25 of Richland township, consisting of about 70 acres, the other in section 1 of Lloyd township, consisting of 130 acres. These areas are included with the muck, as mapped. The surface layer in these areas consists of 10 to 12 inches of a brownish mass of partly decomposed organic matter, mixed with some silt, clay and sand. The subsoil is a dark brownish-gray silty clay loam to silty clay. It is highly calcareous. Sometimes the subsoil is sandy or composed of a mixture of fine sand, coarse sand and gravel. Peat differs from muck only in that the vegetation residues are less decomposed and the plant structure is still evidenced.

The first treatment needed for the reclamation of muck areas is thoro drainage. When this is accomplished, the land should be seeded to grass, preferably timothy and alsike and utilized for pasture for several years. Then corn and other crops may be successfully grown. Sometimes certain vegetable crops are grown and good yields of such crops as tomatoes, potatoes, onions, cabbage and beets may be secured. Fall plowing is desirable and deep plowing is recommended for muck areas. Small grains are apt to produce an overabundance of straw and consequently lodging occurs. Corn usually produces good yields on well drained and decomposed muck. So-called alkali spots occur along the edges of muck areas in some localities and these spots may be reclaimed by thoro drainage and by the liberal application of horse manure or the turning under of a green crop.

WABASH SILT LOAM (26)

The Wabash silt loam is a minor type in the county, covering only 0.3 percent of the total area. It occurs chiefly in the higher bottoms of the Little Sioux river in Lakeville and Okoboji townships. There are no large areas of the type, but the most extensive occurrence is in sections 32 and 33 of Okoboji township.

The surface soil of the Wabash silt loam is a black silt loam to a depth of 10 to 12 inches. The subsoil is a black silty clay loam, becoming slightly mottled with gray and rusty brown at 24 inches and below that point. The texture of the surface soil varies from a fine sandy loam to a heavy silt loam, the heavier texture occurring further away from the stream. In topography the type is level but the natural drainage is better than that of the Lamoure silty clay loam. It is subject to overflow.

Practically all of the Wabash silt loam is utilized for pasture and only a few small areas are cultivated. If it were protected from overflow and well drained, good yields of cultivated crops might be secured. It would then respond to applications of farm manure, lime should be used to remedy acidity and phosphorus fertilizers might prove of value.

APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

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

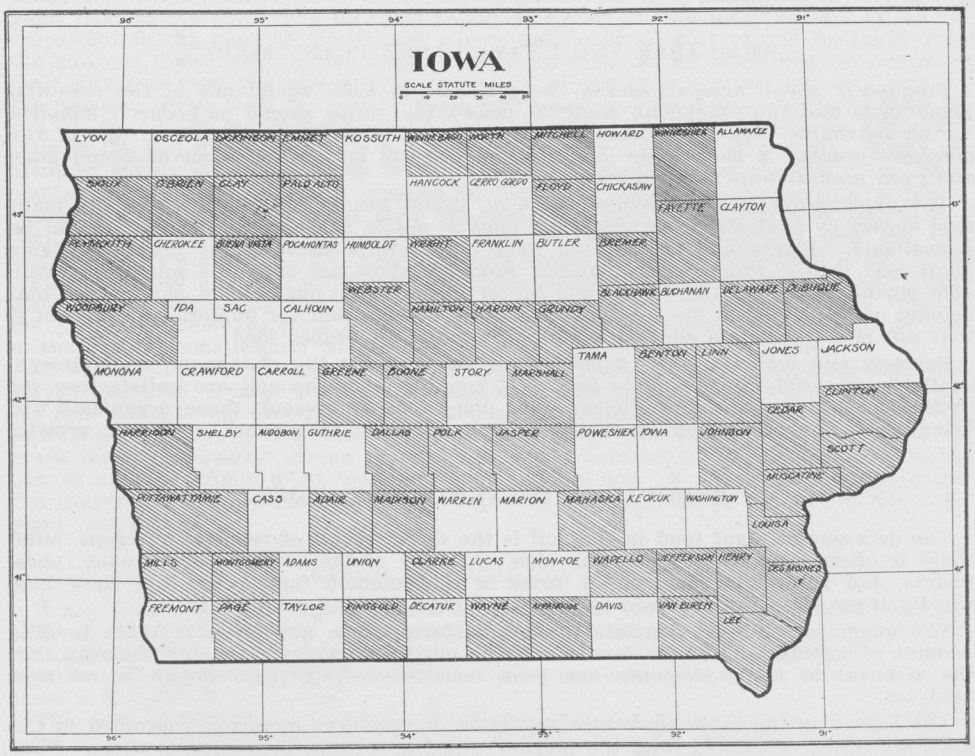


Fig. 15. Map of Iowa showing the counties surveyed.

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

PLANT FOOD IN SOILS

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

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

THE "SOIL DERIVED" ELEMENTS

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

AVAILABLE AND UNAVAILABLE PLANT FOOD

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

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

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

REMOVAL OF PLANT FOOD BY CROPS

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

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

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

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO^3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

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

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

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

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

REMOVAL FROM IOWA SOILS

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

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

PERMANENT FERTILITY IN IOWA SOILS

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

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

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

CULTIVATION AND DRAINAGE

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

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

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

THE ROTATION OF CROPS

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

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

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

MANURING

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

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

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

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

THE USE OF PHOSPHORUS

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

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

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

LIMING

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

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

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

SOIL AREAS IN IOWA

There are five large soil divisions in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 16.

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

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

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

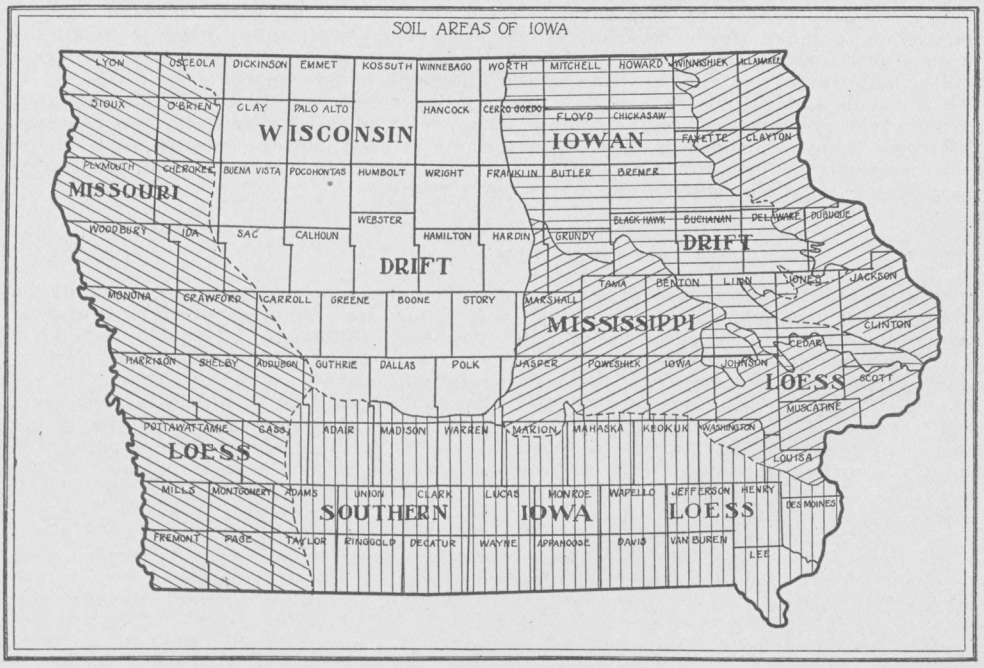


Fig. 16. Map showing principal soil areas in Iowa.

THE SOIL SURVEY BY COUNTIES

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

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

GENERAL SOIL CHARACTERISTICS

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

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

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

The common soil constituents may be given as follows:†

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

SOILS GROUPED BY TYPES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Gravels—More than 50 percent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

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

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

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

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

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

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

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

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