

# SOIL SURVEY OF IOWA WINNESHIEK COUNTY

AGRICULTURAL EXPERIMENT STATION  
IOWA STATE COLLEGE OF AGRICULTURE  
AND MECHANIC ARTS

Agronomy Section

Soils



Soil Survey Report No. 52

June, 1928

Ames, Iowa

# IOWA AGRICULTURAL EXPERIMENT STATION

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June, 1928

Soil Survey Report No. 52

# SOIL SURVEY OF IOWA

Report No. 52—WINNESHIEK COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of T. H. Benton, L. W. Forman,  
H. R. Meldrum and R. E. Bennett



Fig. 1. A typical topography of Winneshiek County.

IOWA AGRICULTURAL  
EXPERIMENT STATION  
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Ames, Iowa

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# WINNESHIEK COUNTY SOILS\*

By W. H. STEVENSON and P. E. BROWN with the assistance of T. H. BENTON, L. W. FORMAN, H. R. MELDRUM and R. E. BENNETT

Winneshiek County is located in northeastern Iowa in the second tier of counties west of the Mississippi River and bordering the state of Minnesota on the north. The location is shown on the accompanying sketch map. The county lies partly in the Iowan drift soil area and partly in the Mississippi loess and, hence, the soils are partly of loessial and partly of glacial origin. The larger part of the county, almost two-thirds of the total area, is covered by loess soils.

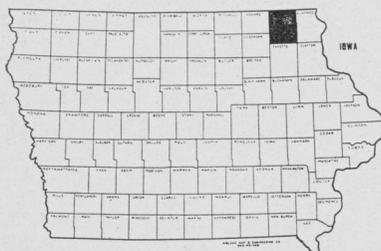


Fig. 2. A map showing the location of Winneshiek County.

The total area of Winneshiek County is 686 square miles, or 439,040 acres. Of this area 430,288 acres, or 98 percent, is in farm land. The total number of farms is 2,860 and the average size of the farms is 150 acres.

The farms are operated by 1724 owners, 508 relative renters, 406 renters and 222 both owning and renting. The following figures taken from the Iowa Year-book of Agriculture for 1926 show the utilization of the farm land in the county:

Acreage in general farm crops.....	245,600
Acreage in farm buildings, public highways and feed lots.....	20,238
Acreage in pasture .....	147,570
Acreage in waste land not utilized for any purpose.....	6,315
Acreage in farm wood lots used for timber only.....	10,132
Acreage in farm lands lying idle.....	290
Acreage in crops not otherwise listed.....	570

The type of agriculture most commonly followed in Winneshiek County at the present time consists of a system of general farming, including the raising and feeding of hogs, cattle and sheep, some dairying and the growing of corn, small grains and hay crops. Hog raising is the most important livestock industry. Cattle raising is practiced less extensively but considerable feeding is done. Sheep raising is practiced on some of the rougher lands and some sheep are shipped in for feeding. Dairying is quite an important industry and has been increasing in importance in recent years. The dairy products make up a large part of the farm income. General farm crops are grown; the chief crops including corn, oats, and timothy and clover. Other crops are grown to a minor extent, some being of importance in individual cases. The growing of fruit is practiced to some extent, and there are a number of commercial orchards. The fruit grown, however, is mostly utilized for home consumption. Trucking is of minor importance, being developed on some of the sandier areas adjacent to the larger towns. Poultry raising is practiced on practically all farms, and the sale of poultry products adds considerable to the farm incomes. The chief commercial interests of the county, from the agricultural standpoint, are centered around the raising of hogs and beef cattle, the dairy industry and the growing of corn and other general farm crops.

\* See Soil Survey of Winneshiek County, Iowa, by T. H. Benton, of the Iowa Agricultural Experiment Station and N. J. Russell, of the U. S. Department of Agriculture.

TABLE I. AVERAGE YIELD AND VALUE OF PRINCIPAL CROPS GROWN IN WINNESHIEK COUNTY, IOWA\*

Crop	Acreage	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn .....	86,242	20.0	40.0	3,449,680	\$ 0.56	\$1,931,820
Oats .....	78,576	18.3	32.0	2,527,541	0.35	884,639
Winter wheat .....	659	0.15	20.0	13,180	1.20	15,816
Spring wheat .....	1,187	0.27	14.0	16,618	1.19	19,775
Barley .....	10,376	2.4	30.0	311,280	0.56	174,316
Rye .....	305	0.07	18.0	5,490	0.82	4,501
Clover hay .....	1,844	0.43	1.55	2,858	15.60	44,584
Timothy hay .....	15,165	3.5	1.01	15,317	12.25	187,633
Clover and timothy hay (mixed) .....	36,791	8.5	1.35	49,668	14.60	725,152
Alfalfa .....	436	0.10	1.87	815	19.50	15,892
Sweet clover .....	223	0.05	-----	-----	-----	-----
Wild hay .....	4,365	1.01	1.23	5,369	12.50	67,112
Soybeans .....	94	0.02	-----	-----	-----	-----
Potatoes .....	937	0.21	49.0	45,913	1.70	78,052
Timothy seed .....	7,533	1.75	3.2	24,323	2.60	63,239
Clover seed .....	211	0.05	0.62	131	16.25	2,128
Flax seed .....	656	0.15	15.0	9,840	1.95	19,188
Pasture .....	147,570	34.0	-----	-----	-----	-----

\* Iowa Yearbook of Agriculture, 1926.

There is a rather large acreage of waste land in the county, and much of this land might be reclaimed and made productive if proper methods of handling were practiced. No general recommendations regarding treatment of waste areas can be given, inasmuch as the causes of the unproductiveness of such areas are variable. In many cases drainage is the first treatment needed to reclaim infertile land, and the installation of tile may be all that is necessary to make such land satisfactorily productive. Frequently, however, other special treatments are necessary, and in a later section of this report suggestions will be offered regarding the best methods of handling the individual soil types occurring in the county. Where the conditions are more or less abnormal, advice regarding desirable treatments for land may be secured upon request from the Soils Section of the Iowa Agricultural Experiment Station.

#### GENERAL FARM CROPS GROWN IN WINNESHIEK COUNTY

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

Corn is the most important crop, both in acreage and value. It covers 20 percent of the total farm land. Average yields of corn amount to 40 bushels per acre. The principal varieties grown include Reid's Yellow Dent, Silver King, Minnesota No. 113, Iowa Silvermine and Calico. The Silver King variety which is so generally grown was originated near Fort Atkinson. About 10 percent of the corn grown, mostly yellow varieties, is used for silage. There are 472 silos in the county. Practically all of the corn is fed on the farms, and in some years considerable corn is shipped in for feeding purposes.

Oats are grown to a slightly smaller extent, and the crop is of less value. Oats are produced on 18.3 percent of the total farm land of the county. Average yields of the crop amount to 32 bushels per acre. In very favorable seasons the

yields are frequently high and yields of 60 to 70 bushels per acre are often obtained. The varieties most commonly grown include Iowa 103, Iowa 105, Early Champion, Green Russian and Iowar, which are all early varieties. The later varieties grown include Silvermine and Goldmine. In some sections Swedish Select is used, and Iogren is grown on a few farms. Farmers generally prefer the early oat varieties. About 25 percent of the oat crop is sold from the farms thru local elevators, Chicago and Minneapolis being the principal markets. The remainder of the crop is used for feeding purposes on the farms.

Clover and timothy mixed is the chief hay crop and the third crop of importance. It is grown on 8.5 percent of the total farm land and yields amount to 1.35 tons per acre. Timothy alone is grown to a considerable extent. In 1926 this crop occupied 3.5 percent of the total farm land, and average yields amounted to 1.01 tons per acre. Much of the timothy grown is used for seed, the remainder being utilized for hay. Some clover is grown alone, average yields of this crop amounting to 1.55 tons per acre. Some alsike clover and occasionally small areas of Hubam clover, sweet clover and Mammoth red clover are found. The hay is fed to work stock and cattle. Occasionally small amounts of hay are sold from the farm.

Barley is grown on rather a considerable area, the land utilized for this crop amounting to 2.4 percent of the total farm land. Average yields of barley amount to 30 bushels per acre. It is usually grown as a substitute for oats in the rotation and is largely used as feed for hogs.

Potatoes are grown in all parts of the county, practically all farms raising sufficient to supply the home demand. Occasionally, small quantities of potatoes are sold on the local market. Average yields amount to 49 bushels per acre.

Wheat was at one time a most important crop but in recent years it has been of less value. Winter wheat averages 20 bushels per acre and spring wheat 14 bushels per acre. In the southeast corner of the county, around Spillville and Calmar, spring wheat is most commonly grown. Part of the winter wheat is used locally but most of it is sold out of the county thru the local elevators. The total value of the wheat crop is not large.

Alfalfa is grown in a small way, average yields amounting to 1.87 tons per acre. The value of this crop is considerable and it might be more extensively grown and would provide considerable income on the farms. Where the land is well limed and the crop is inoculated, very satisfactory yields may be secured. Under satisfactory conditions yields of 3 to 3½ tons per acre are obtained, three cuttings being made in normal seasons. The crop is of particular value for forage purposes on the dairy farm.

Minor crops grown include flax, which is used for seed, buckwheat, millet, rye, sorgo (sweet sorghum), rape and popcorn. Trucking is practiced on small areas, the crop being disposed of on the local markets. The largest areas in vegetables and melons are found around Freeport and near Decorah. Sweet corn is grown on small areas, especially in the southeastern part of the county.

Fruit growing is practiced extensively, most farms having an orchard of from 20 to 80 apple trees. Northwestern Greening, Whitney, Snow, Melinda and Wealthy are the main varieties. Some Ben Davis and a few Delicious are grown. There are a few commercial orchards occupying 5 to 12 acres. There are a few

plum trees, some cherry trees, a few pears and other tree fruits. Small quantities of strawberries, blackberries, raspberries, gooseberries, grapes and currants are raised but not in sufficient quantities for local consumption. In general the fruit raised is not sufficient to supply the local demand.

#### WINNESHIEK COUNTY'S LIVESTOCK INDUSTRY

The livestock industries of Winneshiek County include the raising and fattening of hogs, dairying, the raising and feeding of cattle, the raising of horses and the raising and feeding of sheep. The following figures taken from the Iowa Monthly Crop Report for July 1, 1927, giving the January 1, 1927, estimates of the Bureau of Crop and Livestock Estimates of the U. S. Department of Agriculture show the extent of the livestock industries of the county.

Horses .....	12,800
Mules .....	275
Cattle, all .....	61,500
Hogs .....	102,000
Sheep .....	13,800

The raising of hogs is the most important livestock industry. There are only a few purebred herds, most of the hogs being mixed breeds. The Poland China type predominates with Duroc second. There are a few Chester Whites, Spotted Poland Chinas and Hampshires. The feeding of hogs is practiced extensively and several carloads are shipped in and fed annually. The hogs are marketed on the Chicago, Austin and Cedar Rapids markets.

Cattle raising is extensively practiced. Most of the cattle are grade Short-horns, altho there are some Angus and Herefords. There are a number of purebred herds, mostly Shorthorn with a few Hereford and Angus. Some feeders are shipped in for finishing each year, but most of the cattle fed are raised on the farms. The cattle are marketed in Chicago, St. Paul, Mason City, Austin and Cedar Rapids.

The dairy industry has been developed considerably in recent years and is now quite important. Grade milking Shorthorns are the main type of dairy cattle. Holsteins, Herefords and a few Guernseys are found. The dairy products are sold to the local creameries and local cream buying stations. Considerable butter is manufactured and shipped to the eastern markets. The value of the dairy products is high.

There is some sheep raising carried on, principally on the rougher land. The sheep are mostly Shropshire grades with some Cotswold. A few range feeders are shipped in each year. A considerable amount of wool is produced in the county and is sold to buyers thru the County Cooperative Wool Association. A few goats are also found on some farms.

Horses are raised principally for work stock. The Percheron breed predominates with Belgian second and some Shires and Clydes. Most of the farm work is done with horses, altho a few mules are also used.

Poultry raising is practiced extensively and flocks are maintained on practically all farms, the average size of the flock being from 100 to 150 fowls. Barred Rocks, Rhode Island Reds, Buff Orpingtons and Leghorns are preferred. The value of the poultry products is considerable. Ducks, geese and turkeys are also raised in considerable numbers.

### THE FERTILITY OF WINNESHIEK COUNTY SOILS

In general, the yields of farm crops secured in Winneshiek County are satisfactory, but in many cases much larger crop yields might be secured by the adoption of proper methods of handling the soils. In some areas the land is poorly drained, and the installation of tile is the first treatment needed to make it more satisfactorily productive. Such is the case particularly with the Clyde silty clay loam on the drift upland. A similar condition also occurs in the case of some of the less extensive soil types occurring in the county.

Practically all of the soils of the county are acid in reaction and for the best growth of general farm crops and particularly of legumes such as alfalfa and red clover, applications of lime in sufficient amounts to neutralize the acidity are very necessary. It is very important that the soils of the county be tested for lime needs and that lime be applied in sufficient amounts to neutralize acidity. Liming must be done at regular intervals to prevent the soils from becoming acid again. Only in this way will the best crop growth be secured.

In many cases the supply of organic matter and nitrogen is not overly high and applications of fertilizing materials supplying these constituents is quite desirable. Farm manure is a particularly valuable fertilizer on many of the soils, and large increases in crop yields follow its use. The turning under of all crop residues is essential, especially under a grain system of farming, in order to maintain the organic matter supply of the soil. The use of leguminous crops as green manures is also desirable on many of these soils, especially on those which are coarse in texture and poorly supplied with organic matter and nitrogen.

The phosphorus supply of Winneshiek County soils is inadequate for the needs of crops over a long period of years. The amount present in most of the soils is low and, while there is enough total phosphorus for a number of crops, the content is so low that there is certain to be a deficiency in the production of available phosphorus. The use of phosphate fertilizers would be very desirable on the soils of the county, and the tests carried out with rock phosphate and superphosphate indicate profitable returns from the use of both these materials. It has not yet been possible to determine which phosphate can be employed with the most profit, and farmers are urged to test both phosphates under their particular conditions and determine which can be used most economically.

Erosion occurs to a serious extent in some sections of Winneshiek County, and a number of the soils are injured considerably by this destructive action. Sheet washing occurs to some extent on the rougher areas, and much of the surface soil is washed away where the land is not properly handled. Gullies are formed in many areas and are frequently a serious detriment to the proper utilization of the land. Sheet washing or gullying should be prevented or controlled. A number of methods adapted to various conditions are suggested later in this report.

### THE GEOLOGY OF WINNESHIEK COUNTY

The geological history of Winneshiek County throws little light on the present day soil conditions in that county. The underlying rock materials have been so deeply buried by the deposits of glacial drift and wind laid loess in later ages that the earlier geological formations have slight effect upon the soil conditions.

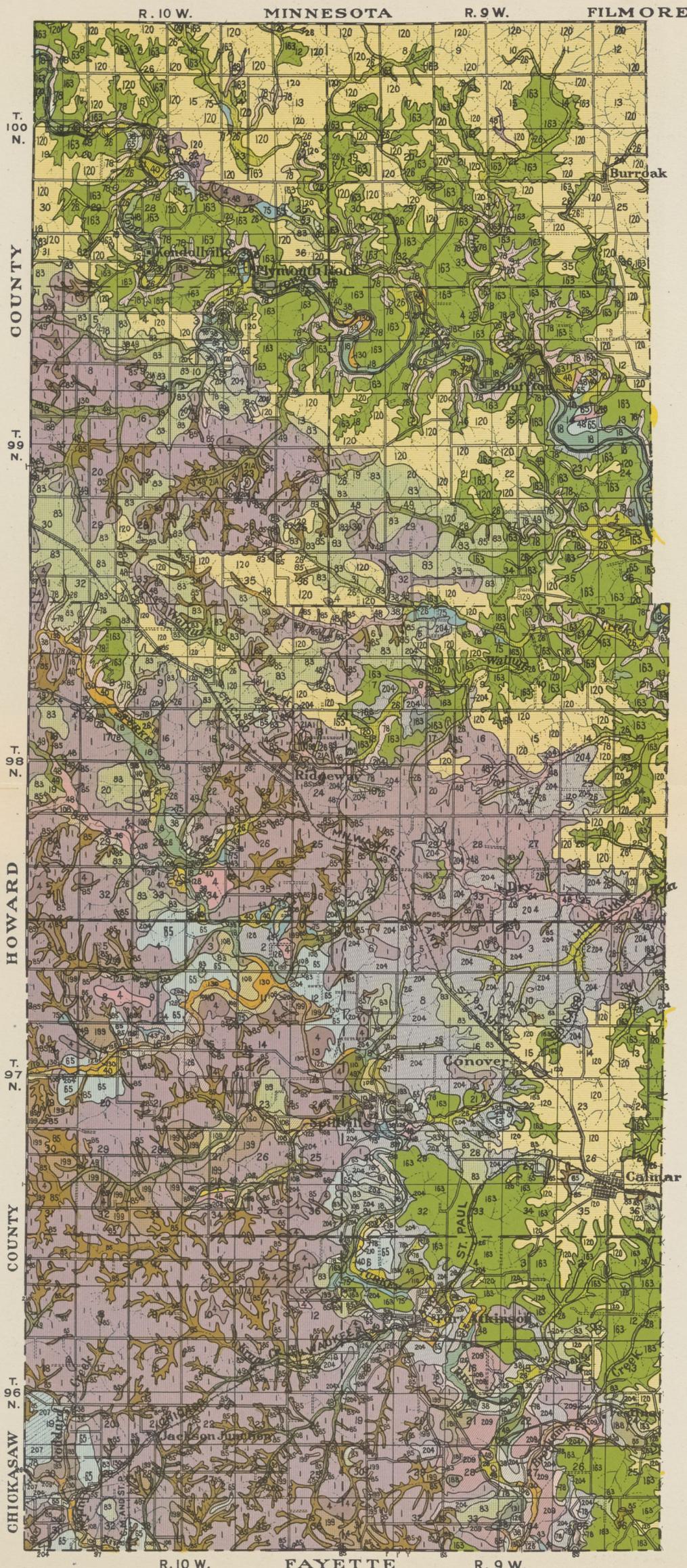
Only in the case of two or three types in the county is the bedrock of importance. There are two soil types, the Boone fine sandy loam and the Dubuque silt loam, both occurring in very limited areas in the county which are derived in large part from the underlying limestone rock. The former occupies an area of 1,344 acres or 0.3 percent of the total area of the county, while the Dubuque silt loam covers 640 acres or 0.1 percent of the total area of the county. A considerable area, which has been mapped as rough stony land, is also partly residual in nature, but the greater portion is covered with glacial material. On the loessial upland the Dodgeville silt loam rests upon limestone at more or less shallow depths, and this soil type is affected, especially in the subsoil, by the underlying lime rock. On the terraces the Millsdale silt loam and the Millsdale loam rest on limestone, and the soils are modified to a greater or less extent, depending upon the depth of the surface soil to the underlying lime rock.

Except for the areas which have been mentioned, the soils of the county are derived from glacial material or a later loessial deposit. At least three times during the glacial age great ice sheets swept over the county and upon their retreat left behind vast deposits of glacial till. The earliest of these glaciations is known as the pre-Kansan. It consisted of a greenish-blue or grayish-blue clay filled with gravel and boulders. None of the soil types occurring in the county are derived from this earlier glaciation but in places the deposit has certainly had some effect on the subsoil conditions of some types.

The second glaciation, known as the Kansan, extended over a large part of the county and left behind a deep deposit of glacial debris. The depth of this deposit varies widely in different parts of the county, being deeper in the western part and thinning out gradually towards the east. This drift material consists of a blue clay containing many boulders and much gravel and sand. When exposed to weathering the material oxidizes to a reddish-brown color, sometimes to a depth of 2 or 3 feet. Below this is a yellowish boulder clay which gradually merges into the blue clay of the original drift. None of the soil types mapped in the county have been derived entirely from this Kansan till as it has been covered by the later deposits, but in the case of the Lindley loam and in the shallow phase of the Lindley, and in the case of the Dickinson sandy loam, the subsoil conditions are evidence of the occurrence of Kansan till.

The third glaciation, the Iowan, extended over about one-third of the county, the northeastern portion not being invaded by this glacier. The deposit left by the Iowan glaciation is relatively thin, ranging from 10 to 20 feet in depth. It consists of a yellow clay containing many boulders and much coarse gravel. There are large areas of soils in the western part of the county which are derived entirely from this Iowan drift material. The soils of the Carrington and Clyde series are formed from this glaciation.

At a later period in geological history, when climatic conditions were different than at present, there was deposited over the drift materials in the eastern two-thirds of the county a very finely divided silty material known as loess. Loess consists of a yellowish, fine grained silty material in its original unweathered condition. Since deposition the loess has been modified considerably by the accumulation of organic matter, and the soils derived from the loess are much darker in color than the original material. There is a wide variation



# WEST SECTION SOIL MAP OF WINNESHIEK COUNTY IOWA

Thomas D. Rice, Inspector, Northern Division. Soils surveyed by  
T. H. Benton, of the Iowa Agricultural Experiment Station, and N.  
J. Russell of the U. S. Dept. of Agriculture.

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS  
H. G. Knight, Chief. Curtis F. Marbut, in charge Soil Survey

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

## LEGEND

<i>Drift Soils</i>		
<b>1</b> Carrington loam	<b>83</b> Carrington silt loam	<b>85</b> Clyde silty clay loam
	<b>65</b> Lindley loam	
<b>207</b> Lindley Loam Shallow Phase	<b>4</b> Carrington fine sandy loam	<b>199</b> Dickinson sandy loam
<i>Loess Soils</i>		
<b>120</b> Tama silt loam	<b>163</b> Fayette silt loam	<b>204</b> Dodgville silt loam
<b>80</b> Clinton silt loam	<b>208</b> Fayette fine sand	
<i>Terrace Soils</i>		
<b>209</b> Millsdale silt loam	<b>108</b> O'Neill loam	<b>75</b> Waukesha silt loam
<b>38</b> Buckner loam	<b>126</b> O'Neill sandy loam	<b>40</b> Buckner sandy loam
<b>188</b> Millsdale loam	<b>81</b> Jackson silt loam	<b>110</b> O'Neill fine sandy loam
<b>131</b> Judson silt loam	<b>97</b> Plainfield fine sandy loam	<b>43</b> Bremer silty clay loam
<i>Swamp and Bottomland Soils</i>		
<b>26</b> Wabash silt loam	<b>18</b> Cass loam	<b>49</b> Wabash loam
<b>48</b> Wabash silty clay loam	<b>130</b> Cass fine sandy loam	<b>21A</b> Muck
	<b>71</b> Genesee silt loam	
<i>Residual Soils</i>		
<b>78</b> Rough stony land	<b>210</b> Boone fine sandy loam	<b>183</b> Dubuque silt loam

SCALE: 1 INCH TO 2 1/2 MILES  
AMERICAN LITHO. & PRINTING CO., DES MOINES, IOWA



Fig. 3. A limestone outcropping in Winneshiek County.

in the thickness of the covering of loess, but it is generally much deeper in the eastern part of the county, thinning out toward the western part where it joins the Iowan drift area. Over three-fifths of the total area of the county, 61.2 percent, is covered by the loess soils. The soils of the Tama, Fayette, Dodgeville and Clinton series are derived from the loess deposits.

Second bottomlands or terraces are developed to some extent along the main streams occurring in Winneshiek County and are classified in the Millsdale, O'Neill, Waukesha, Buckner, Jackson, Judson, Plainfield and Bremer series.



Fig. 4. Limestone bluffs.

Most of the individual areas of terrace soils are small. The higher terraces are classified in the Millsdale, O'Neill, Waukesha, Buckner and Jackson series, while the lower terraces representing more recent formations are classified in the Judson, Bremer and Plainfield series.

The bottomland soils are formed from the loessial and glacial material washed down from the uplands and deposited upon them and they are subject to overflow, hence, there is considerable variation in the soil conditions. The bottomland soils are mapped in the Wabash, Cass and Genesee series. There is also a small area of muck.

#### PHYSIOGRAPHY AND DRAINAGE

A considerable variation in the topographical conditions occurs in various parts of the county. In the western one-third, where the soils are derived from glacial drift, the area is mainly a gently undulating upland plain. Erosion has not occurred so extensively thruout much of this area, and the topography is mainly gently rolling to undulating. There are also extensive flat or depressed areas where drainage conditions are poor, and in some instances the land is even wet or marshy. In these areas the soil mapped as Clyde silty clay loam occurs. This type is also found along the intermittent drainageways and at the heads of the minor streams. In the rougher sections in the glacial portion of the county where the Lindley soils occur the topography is strongly rolling to rough. The same is true of the Dickinson soils which occur on the more strongly rolling areas.

In the eastern two-thirds of the county where the uplands have been covered by the loessial material, the topographic features reflect definitely the characteristics of the soil types. On the more gently rolling areas are found the Tama and Fayette soils, while the Clinton soils occur on the rougher sections. The

same is true of the Dodgeville silt loam which is found on the rougher areas where much of the surface soil has been washed away. The most extensive topographic condition occurring in the loessial part of the county is the gently rolling topography of the Tama silt loam.

The various streams and intermittent drainageways have penetrated into practically all parts of the county, and the interstream areas are broad undulating to rolling uplands. The rougher lands are confined to relatively narrow belts along the sides of the valleys of the larger streams. Narrow strips of bottom-land soils occur along practically all of the larger streams. Along the Upper Iowa

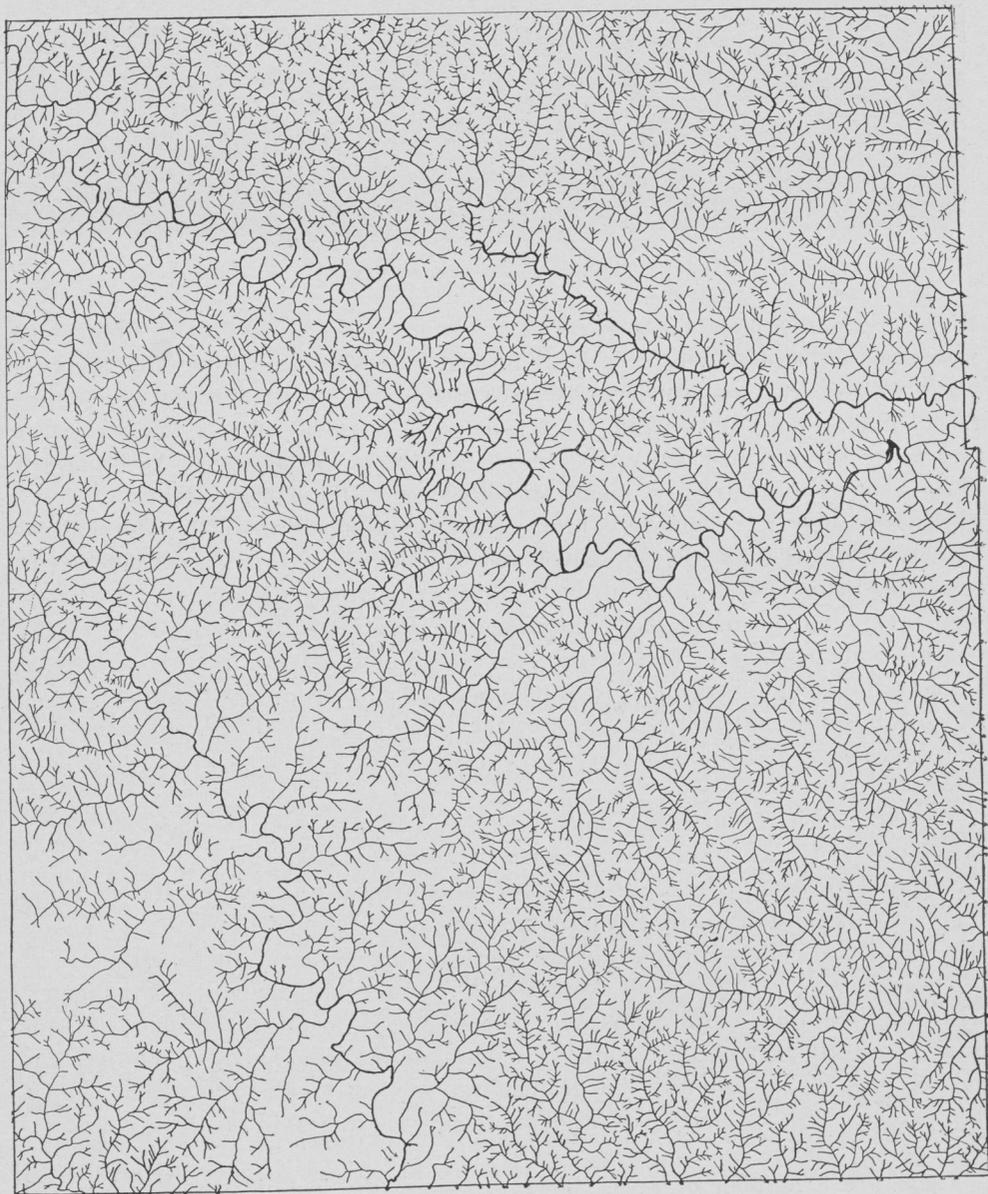


Fig. 5. Map showing the natural drainage system of Winneshiek County

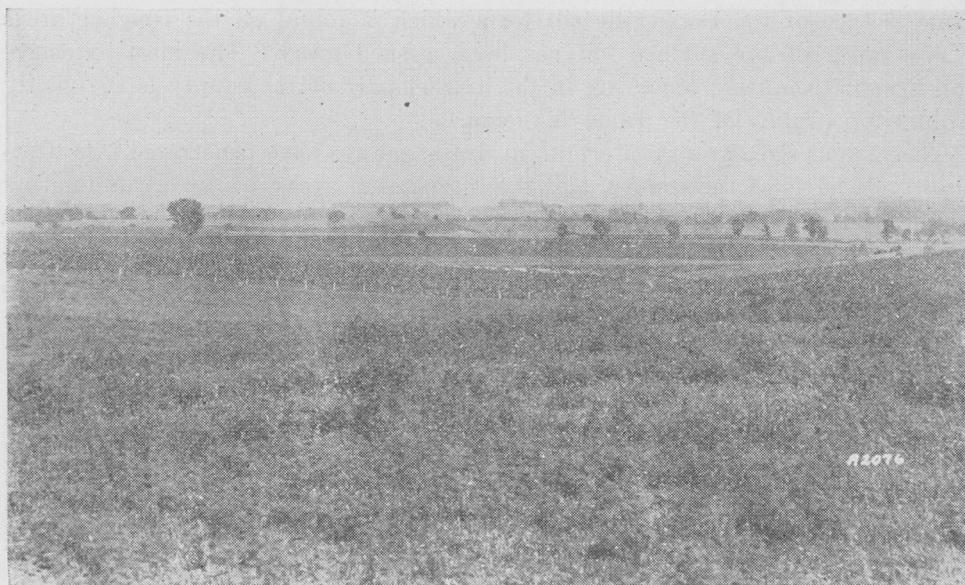


Fig. 6. A typical topography in the less rugged section of Winneshiek County.

River, extending from the northwestern corner of the county to Decorah, narrow areas of bottomlands have been formed between the streams and the rock walls. These areas are usually only a few feet above the streams and are subject to flooding. South of Decorah, terraces have been developed to a greater extent and many 30 to 50 feet above the present flood plain are mapped. Well marked second bottomlands are also found on both sides of the Turkey River.

The drainage of the county is brought about mainly by the Upper Iowa River and its tributaries, the Turkey River and the Yellow River. The tributaries of the latter drain a small area in the southeastern part of the county. A narrow strip along the northern part is drained by Root River. The portion of the county lying north and east of the area of upland, extending thru Ridgeway, Calmar and Ossian, is drained by the Upper Iowa River and its tributaries, most of which are intermittent. Southwest of the high divide of upland just mentioned the drainage is accomplished by the Turkey River, which flows into the Mississippi.

Walnut Creek, Trout Run, Canoe Creek and Paint Creek are the chief tributaries of the Upper Iowa River. Krum Creek, Goddard Creek, Little Turkey River and Brockamp Creek are the chief tributaries of the Turkey River, draining the extreme southeastern part of the county. The north fork of the Yellow River and the Yellow River drain the southeastern corner of the county.

The drainage conditions of Winneshiek County are generally satisfactory, with the exception of the areas of Clyde silty clay loam on the drift uplands in the western part of the county. In most of the remainder of the area the natural streams and intermittent drainageways extend to all parts of the county. The extent of the drainage system of the county is indicated on the accompanying drainage map.

There are a number of areas, however, where the installation of tile would

be of large value. In the case of the Clyde silty clay loam in the drift section of the county, as mentioned above, drainage is the first treatment needed to make the land satisfactorily productive. The type is characteristically poorly drained. Tiling may usually be accomplished without difficulty and considerable areas of naturally fertile soil may thereby be brought under cultivation. Small areas in some of the other upland types would also respond to tiling, but, in general, the upland soils, with the exception of the Clyde, are fairly well drained. On the terraces there are a few types that need drainage; this being particularly true of the Bremer soils. On the bottoms drainage is sometimes needed, but the bottomland soils should first be protected from overflow if crop yields are to be satisfactory.

### THE SOILS OF WINNESHIEK COUNTY

The soils of Winneshiek County are grouped into five classes on the basis of their origin and location; drift, loess, terrace, swamp and bottomland and residual soils. Drift soils are formed from glacial material left behind on the surface of the land when the glaciers retreated. Drift soils are variable in composition and contain numerous boulders, pebbles and much coarse sand. Loess soils are fine dust-like deposits made by the wind at some time when climatic conditions were quite different than at present. Terrace soils are old bottomlands, which have been raised above overflow by a deepening of the river channels or by a decrease in the volume of the streams which deposited them. Swamp and bottomland soils occur in low poorly drained areas along streams and are subject to more or less frequent overflow. Residual soils are formed from the underlying rock material and remain resting upon it. The extent and occurrence of these groups of soils are shown in table II.

By far the largest portion of the county is covered by the loess soils, 61.2 percent being in loess upland. The drift soils are second in importance, covering 21.1 percent of the total area. Terrace soils are of limited occurrence, covering only 3.1 percent. The bottomland soils are more extensively developed, covering 8.6 percent. There are a number of areas of residual soils, the total acreage covered by these types amounting to 6.0 percent of the total area.

There are 31 soil types in the county and these with the areas of the shallow phase Lindley loam, muck and rough stony land make a total of 34 separate soil areas. There are 6 drift soils and the shallow phase Lindley loam, making a total of 7 drift areas, 5 loess soils, 12 terrace types, 6 swamp and bottomland soils and an area of muck, 2 residual soils and the area mapped rough stony land. The areas of the different soil types are shown in table III.

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

Soil Group	Aeres	Percent of total area of county
Drift soils .....	92,608	21.1
Loess soils .....	268,480	61.2
Terrace soils .....	13,248	3.1
Swamp and bottomland soils .....	38,016	8.6
Residual soils .....	26,688	6.0
Total.....	439,040	-----

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN WINNESHIEK COUNTY

Soil No.	Soil type	Acres	Percent of total area of county
DRIFT SOILS			
1	Carrington loam .....	53,056	12.1
83	Carrington silt loam .....	15,360	3.5
85	Clyde silty clay loam .....	12,992	3.0
65	Lindley loam .....	4,096	1.0
207	Lindley loam (shallow phase) .....	576	0.8
4	Carrington fine sandy loam .....	3,328	
199	Dickinson sandy loam .....	3,200	0.7
LOESS SOILS			
120	Tama silt loam .....	135,872	30.9
163	Fayette silt loam .....	112,192	25.6
204	Dodgeville silt loam .....	16,128	3.7
80	Clinton silt loam .....	3,584	0.8
208	Fayette fine sand .....	704	0.2
TERRACE SOILS			
209	Millsdale silt loam .....	2,176	0.5
108	O'Neill loam .....	2,048	0.5
75	Waukesha silt loam .....	1,792	0.4
38	Buckner loam .....	1,792	0.4
126	O'Neill sandy loam .....	1,728	0.4
40	Buckner sandy loam .....	1,344	0.3
188	Millsdale loam .....	640	0.1
81	Jackson silt loam .....	640	0.1
110	O'Neill fine sandy loam .....	448	0.1
131	Judson silt loam .....	384	0.1
97	Plainfield fine sandy loam .....	192	0.1
43	Bremer silty clay loam .....	64	0.1
SWAMP AND BOTTOMLAND SOILS			
26	Wabash silt loam .....	23,488	5.3
18	Cass loam .....	4,416	1.0
49	Wabash loam .....	3,840	0.9
48	Wabash silty clay loam .....	3,520	0.8
130	Cass fine sandy loam .....	1,856	0.4
21a	Muck .....	512	0.1
71	Genesee silt loam .....	384	0.1
RESIDUAL SOILS			
78	Rough stony land .....	24,704	5.6
210	Boone fine sandy loam .....	1,344	0.3
183	Dubuque silt loam .....	640	0.1
	Total .....	439,040	—

The Carrington loam is the largest drift soil and the third most extensively developed individual type. It covers 12.1 percent of the total area. The Carrington silt loam is the second largest drift soil and the seventh most extensively developed type, covering 3.5 percent of the total area. The Clyde silty clay loam is the third largest drift soil and the eighth most extensively developed type. It covers 3.0 percent of the total area. The remainder of the drift soils, the Lindley loam, shallow phase Lindley loam, Carrington fine sandy loam and the Dickinson fine sandy loam are all minor in acreage; the typical Lindley with the shallow phase covering only 1.0 percent and the two remaining types covering less than 1.0 percent.

The Tama silt loam is the largest loess type and the most extensively developed



Fig. 7. A limestone knoll.

individual soil. It covers 30.9 percent of the total area. The Fayette silt loam is the second largest individual type and the second loess soil, covering 25.6 percent of the total area. The Dodgeville silt loam is the third largest loess soil and the sixth most extensively developed type. It covers 3.7 percent of the total area. The remaining loess soils are minor in extent, covering less than 1.0 percent of the total area. None of the terrace soils are extensively developed, the largest, the Millsdale silt loam and the O'Neil loam, cover only 0.5 part of the county. Each of the remainder covers less than half of one percent of the total area.

There are rather extensive areas of swamp and bottomland soils, the Wabash silt loam, the most extensively developed type being the fifth largest individual soil type and covering 5.3 percent of the total area. The Cass loam is second, covering 1.0 percent of the total area. The remainder of the swamp and bottomland soils cover less than 1 percent. There is a rather considerable area of rough stony land covering 5.6 percent of the total area. The residual soils of the Boone and Dubuque series are minor in extent, covering only 0.3 and 0.1 percent, respectively, of the total area.

A rather interesting relationship is evident between the topographic features of the upland soils and the individual soil types. On the glacial uplands the Clyde silty clay loam occurs in the flat to depressed areas of upland. The Carington soils occur on the more gently rolling areas, while the Lindley and Dickinson types are found on the more strongly rolling areas. In the loess section the Tama and Fayette soils occur on the more gently rolling areas, while the Dodgeville and Clinton are found on the more strongly rolling to rough sections. There is very little development of topographic conditions in the terraces, altho a number of the terraces have been eroded to some extent, especially those which are older and high above overflow. This is particularly true of the Jackson and Millsdale soils. On the bottomlands topographic features are of course of very

minor significance. Residual soils show a definite topographic condition usually ranging from strongly rolling to rough.

### THE FERTILITY IN WINNESHIEK COUNTY SOILS

Samples were taken for analyses from each of the soil types in Winneshiek County, except the Carrington silt loam, the shallow phase Lindley loam, the Carrington fine sandy loam, the Bremer silty clay loam and the areas of muck and rough stony land. These soil types are of minor importance in the county and the areas of muck and rough stony land are of no agricultural significance and analyses of the material from them would be of no value. The more extensive soil types were sampled in triplicate, but only one sample was taken in the case of the minor types. All samplings were made with the greatest care to insure results truly representative of the various soil types and that the results would not be affected by the previous treatments of the soil or by any abnormal soil conditions. The samples were secured at three depths, 0 to 6  $\frac{2}{3}$  inches, 6  $\frac{2}{3}$  to 20 inches and 20 to 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 official methods were employed for the phosphorus, nitrogen and carbon determinations and the Truog qualitative test was employed for the limestone requirement determinations. The figures given in the tables are the averages of the results of duplicate determinations on all samples of each type, and they represent, therefore, the averages of two or six determinations.

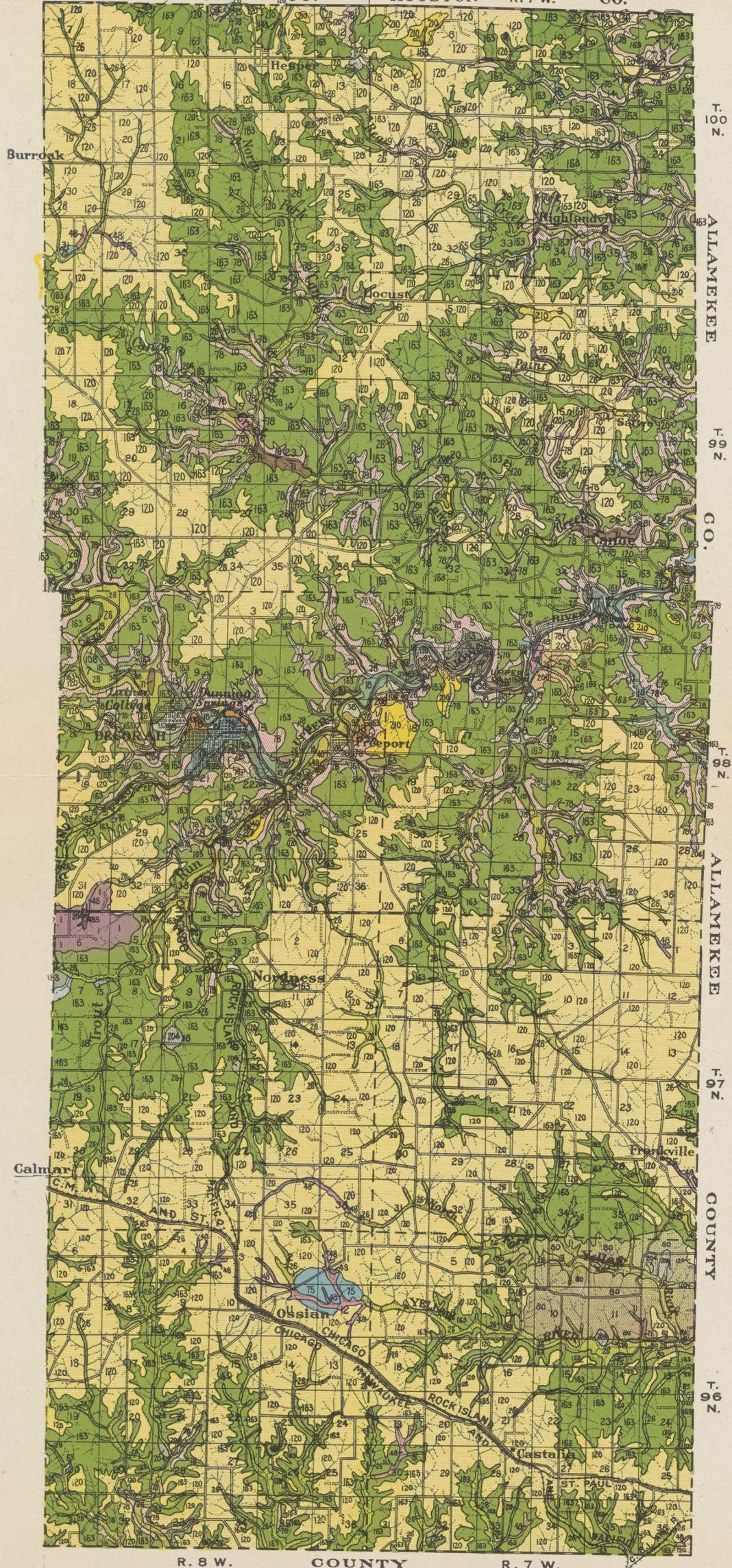
### THE SURFACE SOILS

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

The phosphorus content of the soils of the county varies from 2,565 pounds in the Dubuque silt loam down to 565 pounds in the Plainfield fine sandy loam on the terraces. There seems to be no relationship between the phosphorus supply and the various soil groups, except that the bottomland soils on the average are somewhat better supplied with the element than the upland types. This might be expected inasmuch as there has been more crop growth on the uplands and, hence, more removal of plant food constituents. There is, however, much greater variation in phosphorus content among the soils in the various groups than between groups.

There is some evidence of a relationship between the amount of phosphorus present and the soil series. Thus in the drift soil group, the Carrington and Clyde soils are better supplied than the Lindley and Dickinson soils. On the loess uplands the Tama and Dodgeville soils are better supplied than the Fayette and Clinton soils. On the terraces the Millsdale, the Waukesha and the Judson soils are richer in this element than the O'Neill, Buckner, Jackson and Plainfield soils, and the latter types are the poorest of all. On the bottoms the Wabash soils are a little better supplied than the Cass and Genesee types and, among the residual soils, the Dubuque is much higher in phosphorus than the Boone, in fact the Dubuque is the highest of all the types in the county. The Boone

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# EAST SECTION SOIL MAP OF WINNESHIEK COUNTY IOWA

Thomas D. Rice, Inspector, Northern Division. Soils surveyed by T. H. Benton, of the Iowa Agricultural Experiment Station, and N. J. Russell of the U. S. Dept. of Agriculture.

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS  
H. G. Knight, Chief. Curtis F. Marbut, in charge Soil Survey

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

## LEGEND

<i>Drift Soils</i>		
1 Carrington loam	83 Carrington silt loam	85 Clyde silty clay loam
	65 Lindley loam	
207 Lindley Loam Shallow Phase	4 Carrington fine sandy loam	199 Dickinson sandy loam
<i>Loess Soils</i>		
120 Tama silt loam	163 Fayette silt loam	204 Dodgeville silt loam
80 Clinton silt loam	208 Fayette fine sand	
<i>Terrace Soils</i>		
209 Millsdale silt loam	108 O'Neill loam	75 Waukesha silt loam
36 Buckner loam	126 O'Neill sandy loam	40 Buckner sandy loam
188 Millsdale loam	81 Jackson silt loam	110 O'Neill fine sandy loam
131 Judson silt loam	97 Plainfield fine sandy loam	43 Bremer silty clay loam
<i>Swamp and Bottomland Soils</i>		
26 Wabash silt loam	18 Cass loam	49 Wabash loam
48 Wabash silty clay loam	130 Cass fine sandy loam	21A Muck
	71 Genesee silt loam	
<i>Residual Soils</i>		
78 Rough stony land	210 Boone fine sandy loam	183 Dubuque silt loam

SCALE: 1 INCH TO 2 1/2 MILES

AMERICAN LITHO. & PRINTING CO., DES MOINES, IOWA

TABLE IV. PLANT FOOD IN WINNESHIEK COUNTY, IOWA, SOILS  
Pounds per acre of 2 million pounds of surface soil (0-6 $\frac{2}{3}$ " )

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
DRIFT SOILS						
1	Carrington loam .....	1,310	4,060	49,619	-----	7,000
85	Clyde silty clay loam.....	1,144	3,680	35,340	-----	3,000
65	Lindley loam .....	882	1,240	12,151	-----	3,000
199	Dickinson sandy loam.....	912	1,960	24,927	-----	2,000
LOESS SOILS						
120	Tama silt loam.....	1,213	3,820	40,059	-----	5,000
163	Fayette silt loam.....	943	1,920	22,078	-----	2,500
80	Clinton silt loam.....	996	1,880	21,091	-----	4,000
204	Dodgeville silt loam.....	1,017	5,280	63,373	-----	-----
208	Fayette fine sand.....	572	1,160	16,340	-----	1,000
TERRACE SOILS						
209	Millsdale silt loam.....	1,623	4,760	55,896	-----	5,000
108	O'Neill loam .....	1,071	1,820	29,974	-----	3,000
75	Waukesha silt loam.....	1,582	5,400	57,583	-----	7,000
38	Buckner loam .....	1,373	3,520	47,776	-----	1,000
126	O'Neill sandy loam .....	909	2,440	28,614	-----	3,000
40	Buckner sandy loam.....	1,071	2,040	23,164	-----	4,000
188	Millsdale loam .....	1,535	3,860	38,984	-----	2,000
81	Jackson silt loam.....	1,125	2,740	26,166	-----	3,000
110	O'Neill fine sandy loam....	754	2,440	20,982	-----	2,000
131	Judson silt loam.....	1,468	3,940	46,308	-----	5,000
97	Plainfield fine sandy loam..	565	700	9,649	-----	4,000
SWAMP AND BOTTOMLAND SOILS						
26	Wabash silt loam.....	2,316	5,560	96,861	-----	-----
18	Cass loam .....	1,629	6,200	48,368	12,339	-----
49	Wabash loam .....	1,156	5,100	55,480	-----	-----
48	Wabash silty clay loam.....	2,457	18,800	120,406	-----	-----
130	Cass fine sandy loam.....	1,033	2,680	28,266	2,892	-----
71	Genesee silt loam.....	1,320	2,940	31,795	-----	1,000
RESIDUAL SOILS						
210	Boone fine sandy loam.....	619	1,460	20,012	-----	7,000
183	Dubuque silt loam.....	2,565	2,580	106,117	89,650	-----

series is represented only by a fine sandy type, while the Dubuque is represented by the silt loam. This accounts in large part for the difference in phosphorus content.

The effects of the texture of the various soils is also shown on the phosphorus content. On the loessial uplands the Fayette silt loam is richer than the fine sand. On the terraces the Millsdale silt loam is better supplied than the loam, the O'Neill loam is a little better supplied than the sandy loam or the fine sandy loam. On the bottoms the Wabash silty clay loam is richer than the silt loam or the loam and the silt loam is better supplied than the loam, and the Cass loam is richer than the Cass fine sandy loam. It is apparent from these figures that texture has a very definite effect upon the content of phosphorus in the soil. The finer textured types of the same series seem to be better supplied with the element than the coarser textured soils. The conclusions which have been reached along this line from tests on many soil types in other counties are confirmed. It seems

evident that heavy textured soils may, in general, be expected to contain more plant food constituents than sandy types.

Other factors are also of importance, however, in determining the plant food content of soils and many of these are taken into account in the separation of soils into series. Thus, the color of the soil, the topography, the character of the subsoil and the origin and previous history of the soil all play a part in showing the plant food supply. Soils which are dark in color are richer in phosphorus. Thus the Carrington and Clyde soils are richer than the Lindley and Dickinson soils, the Clinton and Fayette are poorer than the Tama, the O'Neill and Buckner are poorer than the Millsdale, Waukesha and Judson soils and the Wabash are richer than the Cass and Genesee soils. The effect of topographic position plays a part in the determination of plant food content. Thus soils that are level to flat in topography are richer in phosphorus than those which are rolling to rough. The Clyde and Carrington soils are richer than the Lindley and Dickinson and the Tama is richer than the Clinton and Fayette. No comparisons are possible on the terrace and bottomland soils as the topographic features of such soils are not definitely developed. The subsoil character is also of importance. Soils with heavy textured subsoils are generally better supplied with phosphorus than those with sandy, coarse textured subsoils. Again the Clyde and Carrington soils may be mentioned, as they are richer than the Lindley and Dickinson soils and have heavier subsoils. O'Neill soils on the terraces are sandy to gravelly in the subsoil and so are lower in plant food than types like the Waukesha and Judson which have heavier subsoils. Similarly, in the case of the Cass soils on the bottoms the sandy nature of the subsoil indicates that there is less plant food in these soils than in Wabash and Genesee soils. Finally, the origin and previous history of the soils may play a part in showing the content of plant food. Those soils which have developed under forested conditions are poorer than those developed under prairie conditions. For example, the Tama soils, which are of prairie origin, are richer than the Clinton and Fayette, which are of forest origin. The types formed, in part at least, from the earlier glacial material are poorer than those formed from the later deposited material. Thus the Lindley and Dickinson are poorer than the Clyde and Carrington soils.

Generally, a definite relationship is apparent between the phosphorus supply of the soils of this county and the series characteristics of the various soils. Thus a knowledge of the soil type represented will show fairly accurately the phosphorus supply in the soils.

Considering the analyses of the soils as a whole, it is apparent that phosphorus may be a limiting factor in crop growth in the county in the very near future. The supply of the element is not large and the production of available phosphorus may be quite limited at the present time. It seems that there might be a definite need for available phosphorus on these soils now. The tests carried out on some of the soils from this county and reported in the following pages, and the tests made on some of the same soil types in other counties, indicate definitely that rock phosphate or superphosphate may be used with profit on some of these soils at the present time. Definite conclusions regarding the relative value of the two phosphates cannot be drawn from the data available now,

and it is recommended, therefore, that farmers test both phosphates under their own conditions and determine which may be used with the greater profit. Emphasis should be placed upon the fact that the experiments being conducted by the Soils Section of the Iowa Agricultural Experiment Station indicate that one or the other of these phosphorus fertilizers may be used with profit on the soils of the county.

The nitrogen content of the soils varies from 18,800 pounds per acre in the Wabash silty clay loam down to 700 pounds in the Plainfield fine sandy loam. Again there is no evidence of any relationship between the nitrogen content and the soil groups. The only distinct difference is in the case of the bottom-land soils, in which there is more nitrogen, on the average, due to less crop growth and hence a smaller removal of plant food.

The differences in nitrogen content seem to be related to the soil series and to the particular soil types. Differences in color, topography, subsoil character and origin, which are the basis for the separation of the soils into series, and the differences in texture, which are the basis for the separation of types may all be correlated with nitrogen content.

On the drift uplands the Clyde and Carrington soils are richer in nitrogen than the Lindley and Dickinson soils; on the loess uplands the Tama and Dodgeville soils are better supplied with this element than the Clinton and Fayette soils; on the terraces the Millsdale and Waukesha soils are richer than the other terrace types; and on the bottoms the Wabash soils are better supplied than the Cass and Genesee soils. All these comparisons are a reflection of the differences in color, topography, subsoil character and origin of the soils of the different series.

The effects of textural differences are indicated also in the nitrogen content differences of some of the types in the same series but of different textures. Thus, the Fayette silt loam is richer than the fine sand, the Millsdale silt loam is better supplied than the loam. The O'Neill sandy loam and fine sandy loam are a little better supplied than the loam, but this is contrary to the usual results secured and probably indicates some abnormal condition in the particular sample of the O'Neill loam which was analyzed. The Wabash silty clay loam is richer than the silt loam, which in turn is richer than the loam.

It is apparent from these data that the soils of Winneshiek County as a whole are fairly well supplied with nitrogen, but in some instances the amount present is too small for the best crop growth, and in several cases the content is so low that nitrogen will soon be needed for plant food. Nitrogen must not be disregarded, therefore, in planning systems of fertility for the soils of the county. Not only is the supply too low for the best crop growth in some cases, but there is a constant loss of nitrogen in the crops removed and in the drainage water and hence it is necessary that some nitrogen-containing fertilizer be used on these soils at regular intervals to keep up the supply.

Farm manure is the most important natural nitrogen fertilizer, and it returns to the land much of the nitrogen removed by the crops grown. Its use on the soils of this county is very desirable and large increases in crop yields follow its application. By properly preserving and applying the manure produced on the farm, considerable nitrogen may be returned to the soil, and the main-

tenance of this element in the soil is less difficult. On the heavy types of soil large applications of manure should not be made, but on the sandy types manure is particularly desirable and the increases from its application are especially great. Small amounts may be applied with profit, however, even on heavy soils, especially when they are newly drained and brought under cultivation.

The turning under of all crop residues also aids in keeping up the supply of nitrogen in the soil and is particularly important on the grain farm, where farm manure is not produced. Legumes as green manures may also be employed to build up and maintain the nitrogen content of the soil. Green manuring is very important on the grain farm, but is also distinctly valuable on the livestock farm as a means of supplementing the farm manure.

The content of organic carbon in the soils of the county varies in much the same way as does the nitrogen. The Wabash silty clay loam on the bottoms is the highest in organic carbon, as it was in nitrogen, and the Plainfield fine sandy loam is the lowest, as it was in nitrogen. Again there is little relation between the supply of carbon and the soil group, but the effects of the characteristics which are used as a basis for the determination of soil series and soil types are quite definitely shown. The color, the topography, the subsoil character and the origin of the soil all play a part in determining the content of organic carbon. The texture is also of great importance. Black soils are higher in organic matter than the light colored types and heavy textured soils are richer in organic carbon. The types having heavy subsoils are better supplied with organic matter, as are, also, soils developed under prairie conditions. The same relationships are found among the types as were noted in the case of nitrogen. The Carrington and Clyde soils on the drift uplands are richer than the Lindley and Dickinson soils. The Tama and Dodgeville soils on the loess uplands are richer than the Fayette and Clinton soils. The Millsdale, Waukesha and Judson soils are richer than the other terrace types and the Wabash soils are better supplied than the Cass and Genesee soils.

While the soils of the county are fairly well supplied with organic matter, some types are in need of it. On all the types organic matter must be supplied at regular intervals if the supply is to be kept up. The use of farm manure is necessary in this connection, and the turning under of leguminous crops as green manures is a desirable means of supplementing the farm manure. The proper utilization of all crop residues is also strongly urged as a means of maintaining the organic matter in the soils.

The only soils in the county which show any content of inorganic carbon are the Cass loam and fine sandy loam on the bottoms and the Dubuque silt loam, a residual soil. All the other soils lack this constituent and so are acid in reaction and in need of lime. Some of the types are very acid in reaction and in such cases the necessity for the use of lime is particularly evident. For the best growth of all farm crops, especially legumes, soils should be basic in reaction. If they are acid, crop yields will be restricted and with such legumes as red clover, alfalfa and sweet clover it may not be possible to obtain a satisfactory crop. All the soils of the county, except the Cass and the Dubuque soils, should be tested for reaction and lime needs, and lime should be applied as needed for optimum crop growth. The only way to determine whether or not a soil is acid

TABLE V. PLANT FOOD IN WINNESHIEK COUNTY, IOWA, SOILS  
Pounds per acre of 4 million pounds of subsurface soil (6 $\frac{3}{8}$ "-20")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
DRIFT SOILS						
1	Carrington loam .....	2,208	5,320	65,648	-----	8,000
85	Clyde silty clay loam.....	2,020	3,200	26,424	-----	2,000
65	Lindley loam .....	1,347	1,720	16,262	-----	2,000
199	Dickinson sandy loam.....	1,669	2,220	23,593	-----	3,500
LOESS SOILS						
120	Tama silt loam.....	2,120	4,880	49,688	-----	5,500
163	Fayette silt loam.....	1,973	3,520	41,689	-----	2,000
80	Clinton silt loam.....	2,074	1,960	16,152	-----	6,000
204	Dodgeville silt loam.....	1,520	8,720	93,378	-----	-----
208	Fayette fine sand.....	1,266	1,920	39,644	-----	-----
TERRACE SOILS						
209	Millsdale silt loam.....	2,828	7,800	97,516	-----	5,000
108	O'Neill loam .....	1,426	2,760	20,544	-----	2,000
75	Waukesha silt loam.....	2,640	7,800	100,328	-----	7,000
38	Buckner loam .....	2,545	6,360	83,952	-----	2,000
126	O'Neill sandy loam.....	1,804	2,200	29,966	-----	2,000
40	Buckner sandy loam.....	1,683	1,600	16,686	-----	1,000
188	Millsdale loam .....	2,410	4,400	49,048	-----	2,000
81	Jackson silt loam.....	1,480	2,320	11,898	-----	4,000
110	O'Neill fine sandy loam.....	1,629	2,160	19,954	-----	1,000
131	Judson silt loam.....	4,457	11,640	272,980	-----	4,000
97	Plainfield fine sandy loam....	1,293	2,000	15,492	-----	2,000
SWAMP AND BOTTOMLAND SOILS						
26	Wabash silt loam.....	3,890	7,500	183,914	-----	1,000
18	Cass loam .....	2,774	7,820	66,642	35,378	-----
49	Wabash loam .....	2,342	3,320	41,637	-----	-----
48	Wabash silty clay loam.....	2,828	6,600	74,492	-----	-----
130	Cass fine sandy loam.....	1,899	3,980	44,419	7,037	-----
71	Genesee silt loam.....	2,545	4,760	58,060	-----	1,000
RESIDUAL SOILS						
210	Boone fine sandy loam.....	955	960	4,800	-----	5,000
183	Dubuque silt loam (no sample) .....	-----	-----	-----	-----	-----

and in need of lime is to have it tested and this is also the only way to determine how much lime should be applied. One test will not suffice for all time. The soils should be tested at regular intervals preferably once in the rotation, just preceding the legume crop and then proper conditions in the soil for the best growth of the legume may be insured.

#### 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 analyses of the surface soils seem to indicate definitely the needs of the soils of the county, and it is not necessary to consider the analyses of the lower soil layers in detail. There is no large content of plant food in the lower soil layers of any of the types in the county and hence any deficiency in the surface soils cannot be supplied from below. In some cases there is actually less plant

TABLE VI. PLANT FOOD IN WINNESHIEK COUNTY, IOWA, SOILS  
Pounds per acre of 6 million pounds of subsoil (20"-40")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
DRIFT SOILS						
1	Carrington loam .....	2,650	4,440	54,520	-----	8,000
85	Clyde silty clay loam.....	3,333	2,640	22,064	-----	-----
65	Lindley loam .....	2,282	3,000	17,322	-----	3,000
199	Dickinson sandy loam.....	2,079	1,200	6,381	-----	1,000
LOESS SOILS						
120	Tama silt loam.....	2,877	3,660	35,808	-----	4,500
163	Fayette silt loam.....	2,817	3,240	24,779	-----	2,500
80	Clinton silt loam.....	3,192	2,280	13,744	-----	8,000
208	Fayette fine sand.....	1,838	320	26,552	-----	-----
TERRACE SOILS						
209	Millsdale silt loam (no sample) .....	-----	-----	-----	-----	-----
108	O'Neill loam .....	2,019	1,320	18,816	-----	2,000
75	Waukesha silt loam.....	2,726	4,940	51,961	-----	7,000
38	Buckner loam .....	3,293	5,400	74,212	-----	3,000
126	O'Neill sandy loam.....	2,667	1,800	20,938	-----	1,000
40	Buckner sandy loam.....	2,353	2,160	15,539	-----	1,000
188	Millsdale loam .....	2,444	3,000	29,915	-----	2,000
81	Jackson silt loam.....	2,745	2,160	11,453	-----	4,000
110	O'Neill fine sandy loam.....	1,857	2,160	8,181	-----	-----
131	Judson silt loam.....	6,447	13,920	192,224	-----	6,000
97	Plainfield fine sandy loam....	1,635	320	8,200	-----	1,000
SWAMP AND BOTTOMLAND SOILS						
26	Wabash silt loam.....	4,281	4,200	52,570	-----	-----
18	Cass loam .....	2,181	2,400	28,281	15,038	-----
48	Wabash silty clay loam.....	3,837	2,520	34,456	-----	-----
130	Cass fine sandy loam.....	2,019	2,580	24,498	-----	-----
71	Genesee silt loam.....	3,696	7,440	52,332	-----	1,000
RESIDUAL SOILS						
210	Boone fine sandy loam.....	1,535	-----	8,276	20,244	-----
183	Dubuque silt loam (no sample) .....	-----	-----	-----	-----	-----

food in the lower layers, and in such instances the need for that particular element is even greater than is indicated by the analyses of the surface soil. The data given in tables V and VI merely serve to emphasize the needs of the soils. The supply of phosphorus is low in the soils, and the need of phosphorus fertilizers in the near or immediate future is evident. The nitrogen and organic carbon contents are not high, and these constituents must be supplied regularly if the supply is to be kept up. The same types which were acid in the surface soil show no lime content in the subsurface soil or subsoil, and hence the necessity of testing the soils and applying lime as needed is emphasized.

### GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Winneshiek County in the attempt to secure some information regarding the fertilizer needs of the soils and the value of certain fertilizing materials. These tests were made on

the Tama silt loam and the Fayette silt loam, two of the most important types in the county. In addition greenhouse experiments on the Tama silt loam from Black Hawk County, on the Carrington loam and Fayette silt loam from Fayette County, on the Carrington silt loam from Floyd County, on the Carrington silt loam from Mitchell County and on the Carrington loam from Marshall County are included, as these types all occur in Winneshiek County, and the results secured may be considered definitely applicable to the soils of this county.

The treatments used in all the experiments included manure, limestone, rock phosphate, superphosphate and a complete commercial fertilizer. The amounts of these fertilizers added were the same as those used in the field tests. The results of the greenhouse experiments may, therefore, be considered to show rather accurately the needs of the soils in the field. Manure was added at the rate of 10 tons per acre, and lime was added in sufficient amounts to neutralize the acidity of the soil and supply 2 tons additional. Rock phosphate was added at the rate of 2,000 pounds per acre, superphosphate at the rate of 200 pounds per acre, and the standard 2-12-2 brand of a complete commercial fertilizer was added at the rate of 267 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 instances only the clover yields were secured.

#### RESULTS ON TAMA SILT LOAM

The results of the experiment on the Tama silt loam from Winneshiek County are given in table VII, the figures being the averages of the yields on the duplicate pots. Manure brought about an increase in the yield of wheat, and it also showed a very distinct increase in the yield of clover. Lime with manure gave an increase in the wheat but showed a much larger beneficial effect on the clover. The rock phosphate and superphosphate applied with the manure and lime had about the same effects; the superphosphate showed up slightly better than the rock, but the differences were not great enough to be significant. The complete commercial fertilizer had about the same effect as the phosphates.

The results as a whole, indicate the value of manure and lime on this soil and they show, too, the value of adding a phosphate fertilizer. The results do not permit a comparison between the value of the rock phosphate and the superphosphate, but, evidently, one or the other of these phosphates may be used with profit on this soil.

#### RESULTS ON FAYETTE SILT LOAM

The data secured in the experiment on the Fayette silt loam from Winneshiek County are given in table VIII. The manure did not show any effect on the

TABLE VII. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, WINNESHIEK COUNTY

Plot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check .....	3.8	16.3
2	Manure .....	4.8	19.0
3	Manure + lime .....	5.4	21.0
4	Manure + lime + rock phosphate .....	6.1	23.7
5	Manure + lime + superphosphate .....	6.5	23.8
6	Manure + lime + complete commercial fertilizer ..	6.5	23.5



Fig. 8. Clover in greenhouse experiment on Tama silt loam, Winneshiek County.

wheat crop but brought about an increase in the clover. Manure ordinarily gives distinct increases in the yields of general farm crops on this soil, and the results secured here must be considered somewhat abnormal. Lime with manure gave very definite increases in the yield of wheat and also of the clover. The two phosphates and the complete commercial fertilizer showed about the same effects on both crops, giving slight increases in the yields. The superphosphate was somewhat better on the clover than the other materials but gave about the same effect on the wheat as the complete commercial fertilizer. These results indicate definitely the value of applications of manure to this soil, the value of the use of lime and the possible economic importance of the addition of a phosphorus fertilizer. Whether superphosphate or rock phosphate should be employed cannot be stated positively as both materials gave crop increases and the differences in yields were not sufficiently great to permit definite conclusions. It is apparent, however, that one or the other phosphorus carrier may be used profitably on this soil.

#### RESULTS ON TAMA SILT LOAM FROM BLACK HAWK COUNTY

The results secured on the Tama silt loam from Black Hawk County are given in table IX. Manure had little effect on the wheat, but there was an enormous increase in the clover. Lime also gave little effect on the wheat but brought about a very large increase in the clover. This effect might be looked for, as clover is much more sensitive to acidity than the grain crops. Rock phosphate applied with the manure and lime increased the wheat yields and also gave some effect on the clover. Superphosphate had no effect on the wheat but brought about a considerable increase in the clover. The complete commercial fertilizer

TABLE VIII. GREENHOUSE EXPERIMENT, FAYETTE SILT LOAM, WINNESHIEK COUNTY

Plot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check .....	3.5	14.1
2	Manure .....	3.3	15.7
3	Manure + lime .....	4.3	19.6
4	Manure + lime + rock phosphate .....	4.3	20.4
5	Manure + lime + superphosphate .....	4.9	22.2
6	Manure + lime + complete commercial fertilizer ..	5.0	19.3



Fig. 9. Wheat and clover in greenhouse experiment on Tama silt loam, Winneshiek County.

increased the wheat yields but to a smaller extent than did the rock phosphate. It also increased the yield of clover but had less effect on that crop than the superphosphate. It seems evident that on this type manure and lime show distinct beneficial effects, particularly on clover, and phosphate fertilizers will probably give profitable returns. No definite conclusions can be drawn regarding the relative merits of the two phosphates. The complete commercial fertilizer is evidently less desirable for use than a phosphate.

#### RESULTS ON CARRINGTON LOAM FROM FAYETTE COUNTY

The results of the experiment on the Carrington loam from Fayette County are given in table X. Manure brought about a distinct increase in the clover and the addition of lime gave a still further increase. The rock phosphate, superphosphate and complete commercial fertilizer all gave definite increases



Fig. 10. Clover on Tama silt loam in greenhouse experiment, Black Hawk County.

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

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check .....	12.00	8.0
2	Manure .....	12.65	31.0
3	Manure + lime .....	12.86	51.5
4	Manure + lime + rock phosphate .....	14.03	57.0
5	Manure + lime + superphosphate .....	12.72	64.5
6	Manure + lime + complete commercial fertilizer ..	13.67	59.5



Fig. 11. Wheat and clover on Tama silt loam, Black Hawk County.

on the clover, the superphosphate proving slightly less effective than the other two materials. It seems from these results that the Carrington loam will respond profitably to applications of farm manure, lime and a phosphate fertilizer. The results are not definite enough to show whether rock phosphate or superphosphate should be used, and farmers should test the two materials on their own soils in order to determine which will give the most profitable results. There is no evidence that the complete commercial fertilizer will prove as desirable for use as a phosphate.

TABLE X. GREENHOUSE EXPERIMENT, CARRINGTON LOAM,  
FAYETTE COUNTY

Pot No.	Treatment	Weight of green clover in grams
1	Check .....	4.53
2	Manure .....	15.87
3	Manure + lime .....	18.14
4	Manure + lime + rock phosphate .....	29.48
5	Manure + lime + superphosphate .....	24.94
6	Manure + lime + complete commercial fertilizer .....	29.48



Fig. 12. Clover on Fayette silt loam, Winneshiek County.

#### RESULTS ON FAYETTE SILT LOAM FROM FAYETTE COUNTY

The data secured in the test on the Fayette silt loam from Fayette County are given in table XI, only the yields of clover being given. Again there was a large effect from the application of manure on the clover crop. Lime in addition to manure gave over twice as large a crop as that secured with manure alone. Rock phosphate had little effect in addition to the lime and manure, but superphosphate and the complete commercial fertilizer both proved beneficial, the superphosphate showing up better than the complete fertilizer. The value of the superphosphate on this soil is shown very definitely in these results, and it seems to be very much superior to rock phosphate. Further tests are necessary before definite conclusions can be drawn. These results on the Fayette silt loam indicate that manure, lime and phosphorus are necessary treatments for the best crop production on this type.



Fig. 13. Wheat and clover on Fayette silt loam, Winneshiek County.

TABLE XI. GREENHOUSE EXPERIMENT, FAYETTE SILT LOAM,  
FAYETTE COUNTY

Pot No.	Treatment	Weight of green clover in grams
1	Check .....	24.94
2	Manure .....	31.75
3	Manure + lime .....	81.64
4	Manure + lime + rock phosphate .....	88.45
5	Manure + lime + superphosphate .....	142.88
6	Manure + lime + complete commercial fertilizer .....	111.13

## RESULTS ON CARRINGTON SILT LOAM FROM FLOYD COUNTY

The results of the tests on the Carrington silt loam from Floyd County are given in table XII. The application of manure increased the yields of both the wheat and clover crops to a considerable extent. Lime with manure increased still further the yields of the two crops. An increase might be expected on the clover of the rotation but would hardly be looked for on the wheat, but a very beneficial effect was noted on this wheat crop. Rock phosphate with the manure and lime showed a considerable increase in the clover crop and brought about an appreciable gain in the wheat. Superphosphate with the manure and lime showed a much greater effect on the clover crop but had about the same effect on the wheat as did the rock phosphate. The complete commercial fertilizer with the manure and lime showed about the same effect on the wheat as did the phosphates, but it had a greater effect on the clover than the rock phosphate, altho a smaller influence than that given by the superphosphate was evidenced.



Fig. 14. Wheat in greenhouse experiment on Carrington silt loam, Mitchell County.



Fig. 15. Wheat and clover on Carrington loam, Marshall County.

#### RESULTS ON CARRINGTON SILT LOAM FROM MITCHELL COUNTY

The results secured on the Carrington silt loam from Mitchell County are given in table XIII. The manure brought about a distinct increase in both the wheat and clover crops, the effect being particularly evident on the clover. Lime increased the wheat yield slightly, but with the clover crop the yield was more than doubled. The rock phosphate, the superphosphate and the complete commercial fertilizer showed no effect on the clover but brought about distinct increases in the yields of wheat.

These data confirm those already reported in showing the value of applications of manure, lime and a phosphate fertilizer to this soil.

#### RESULTS ON CARRINGTON LOAM FROM MARSHALL COUNTY

The results obtained in the experiment on the Carrington loam from Marshall County are shown in table XIV. The value of applying manure to this soil is definitely evident in these results. There was a large increase in the wheat

TABLE XII. GREENHOUSE EXPERIMENT, CARRINGTON SILT LOAM, FLOYD COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check .....	6.9	11.6
2	Manure .....	8.4	14.4
3	Manure + lime .....	10.2	15.6
4	Manure + lime + rock phosphate .....	11.5	18.0
5	Manure + lime + superphosphate .....	11.1	23.9
6	Manure + lime + complete commercial fertilizer ..	11.0	19.2

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

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check .....	16.93	10.5
2	Manure .....	19.56	16.0
3	Manure + lime .....	20.93	36.5
4	Manure + lime + rock phosphate .....	22.39	27.0
5	Manure + lime + superphosphate .....	23.55	26.0
6	Manure + lime + complete commercial fertilizer ..	23.67	36.5

yields, and the clover crop was more than doubled by the application of the manure. Lime in addition to manure had a slight influence on the yield of wheat but showed no effect on the clover. Ordinarily, however, this soil will respond definitely to applications of lime when legume crops are to be grown, and the use of lime on the type is certainly to be recommended. The rock phosphate, the superphosphate and the complete commercial fertilizer applied with the manure and lime all brought about distinct increases in the yields of both

TABLE XIV. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, MARSHALL COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check .....	16.5	22.68
2	Manure .....	24.0	45.36
3	Manure + lime .....	25.0	40.82
4	Manure + lime + rock phosphate .....	27.0	49.89
5	Manure + lime + superphosphate .....	27.5	54.43
6	Manure + lime + complete commercial fertilizer ..	26.0	49.89

the wheat and clover crops. There was very little difference in the effect on the wheat, but the superphosphate showed up much better than the other two materials with the clover.

### FIELD EXPERIMENTS

One field experiment is under way in Winneshiek County. Altho the results have been secured for only three years, the data are given here because they indicate definitely the response of the Tama silt loam, the most extensive soil



Fig. 16. Clover on Carrington silt loam, Floyd County.

type in the county, to certain fertilizer treatments. In addition, the results of experiments which have been carried out for a number of years in other counties, are given, inasmuch as these tests have been located on fields in which the soil types are the same as those occurring extensively in Winneshiek County. The conclusions from these tests may, therefore, be considered applicable to Winneshiek County. The results secured on the Carrington loam in the Maynard Field, Fayette County; on the Tama silt loam in the Hudson Field, Black Hawk County; on the Carrington loam in the Jesup Field, Black Hawk County; on the Carrington loam in the Waverly Field No. 2, Series I and II, Bremer County; on the Carrington silt loam in the Springville Field, Linn County; and on the Carrington silt loam in the Osage Field, Mitchell County, are included.

The field experiments are all planned to determine the relative value of various soil treatments. They are laid out on land which is entirely representative of the particular soil types in the county. They are permanently located by the installation of corner stakes, and all precautions are taken in the application of fertilizers and in the harvesting of crops to insure the securing of accurate results. The plots are 155 feet 7 inches by 28 feet or one-tenth of an acre in size.

The fields generally include tests under the livestock and grain systems of farming. In the former, manure is applied, while, in the latter, crop residues are utilized in place of manure. Other fertilizing materials tested include limestone, superphosphate, rock phosphate, a complete commercial fertilizer and muriate of potash. Manure is applied at the rate of 8 tons per acre once in a four-year rotation. The crop residues treatment consists in plowing under the corn stalks which have been cut with a disk or stalk cutter and plowing under at least the second crop of clover. Sometimes the first crop of clover is cut and allowed to remain on the land to be plowed under with the second. Lime is added in sufficient amounts to correct the acidity of the soil. Rock phosphate was added at the rate of 2,000 pounds per acre once in the four-year rotation, until 1925 when the application was reduced to 1,000 pounds per acre once in four years. Superphosphate is added at the rate of 150 pounds per acre on the three grain crops of the four-year rotation; it being disced in in the spring. Until 1923 the old standard 2-8-2 complete commercial fertilizer was used. Since then, the new standard 2-12-2 is employed and applications are made at the rate of 202 pounds per acre annually, thus applying the same amount of phosphorus as that contained in the superphosphate. Muriate of potash is applied at the rate of 25 pounds per acre annually.

#### THE OSSIAN FIELD

The results secured on the Tama silt loam on the Ossian Field, Series I, in Winneshiek County are given in table XV. The application of manure brought about a distinct increase in the yields of the corn in 1925 and the clover in 1927 but showed no effect on the oats in 1926. Lime with the manure gave definite increases in the yields of all three crops. Rock phosphate with manure and lime increased the corn and clover but had no effect on the oats. Superphosphate with the manure and lime gave very similar increases to those brought about by the rock phosphate, showing slightly greater effects on the clover but having a lesser effect on the corn. The muriate of potash applied with the manure, lime

TABLE XV. FIELD EXPERIMENT, TAMA SILT LOAM, WINNESHIEK COUNTY, OSSIAN FIELD—SERIES I.

Plot No.	Treatment	(1)	(2)	(3)
		1925 Corn bushels per A.	1926 Oats bushels per A.	1927 Clover tons per A.
1	Check .....	57.9	49.7	1.62
2	Manure .....	66.0	33.9	1.82
3	Manure+limestone .....	67.5	45.9	1.99
4	Manure+limestone+rock phosphate .....	77.5	38.7	2.29
5	Check .....	60.2	34.5	1.51
6	Manure+limestone+superphosphate .....	76.4	39.9	2.40
7	Manure+limestone+superphosphate+potassium .....	75.1	46.8	2.47
8	Manure+limestone+complete commercial fertilizer..	68.7	54.5	2.42
9	Check .....	59.0	32.7	0.69

(1) Poor stand on plot 8.

(2) Oats badly rusted.

(3) Red clover, alsike clover and timothy.

and superphosphate, showed no effect on the corn but brought about a gain in the oats and in the clover. The complete commercial fertilizer showed much less effect than the phosphates on the corn but had a much greater effect than any other treatment on the oats. A much larger yield was secured than that brought about by the addition of the muriate of potash with the superphosphate, manure and lime. On the clover the complete fertilizer had about the same effect as the superphosphate.

These results indicate definitely the value of a liberal application of manure to this soil. The soil is acid in reaction, and the proper addition of lime will bring about increases in both legume and grain crops. The value of a phosphate fertilizer on the soil is clearly shown. Whether superphosphate or rock phosphate should be employed cannot be definitely stated. The results do not indicate sufficiently large differences between the effects of the two materials. Muriate of potash may be of economic value under special conditions, but tests should be carried out before the material is used extensively. A complete commercial fertilizer may be of value under some conditions, but these results indicate that superphosphate or rock phosphate may prove as satisfactory and they are less expensive.

#### THE MAYNARD FIELD

The results secured on Carrington loam on the Maynard Field, in Fayette County, are given in table XVI. Manure increased the yields of all the crops grown on this field. The beneficial effects were particularly noticeable on the corn in 1923 and on the clover in 1926, but considerable increases were also noted on the oats in 1925. Lime with the manure gave increases in most cases, the effects being particularly evident on the corn in 1922 and on the oats in 1925. The clover in 1926 showed no effect from the lime which is contrary to the usual results. Ordinarily, the clover or other legume of the rotation shows a distinct beneficial effect from lime. The soil is acid in reaction and should be limed in order to bring about the best crops of legumes. Other crops of the rotation may also be benefitted considerably by the use of lime. The addition of rock phosphate with the manure and lime gave definitely beneficial effects in most cases. The corn in 1923, the oats in 1924, the oats in 1925 and the clover in 1926 were

all increased, the latter crop showing the greatest benefit. The superphosphate with manure and lime showed beneficial effects in some cases exceeding the rock phosphate and in other instances having a lesser effect. On the oats in 1924 and 1925 the superphosphate gave a much greater effect than did the rock phosphate, but in 1922 and 1923 the rock was somewhat superior. The effects on the clover in 1926 were about the same from the use of the two materials. The application of muriate of potash with the superphosphate, manure and lime showed beneficial effects in most cases. Only on the oats in 1925 was there no effect. The clover in 1926 was increased considerably. The complete commercial fertilizer had practically identical effects to those brought about by the superphosphate. Only in one case did the complete fertilizer give any greater influence, and then the difference was slight.

These results emphasize the importance of the liberal use of manure on this soil, which is acid in reaction and, therefore, needs lime. The proper application of lime will bring about definite increases in the yields of legumes and often in the yields of other general farm crops. A phosphate fertilizer is strongly recommended, and profitable increases will undoubtedly be secured from the use of rock phosphate or superphosphate. Which material should be employed cannot yet be stated, as the results with the two fertilizers were so much alike. The use of muriate of potash may be profitable under some conditions, but tests should be carried out before this fertilizer is used extensively. The application of a complete commercial fertilizer would not seem from these results to be as profitable as the use of superphosphate. The latter gave quite as large crop increases and it is less expensive.

## THE HUDSON FIELD

The results secured on the Tama silt loam on the Hudson Field in Black Hawk County are given in table XVII. The beneficial effect of applications of manure on this soil type is evidenced by the increased crop yields secured in every season. In some cases very large increases were obtained, as, for example, on the oats in 1919, on the corn in 1920, on the oats in 1922 and 1924, on the timothy in 1926

TABLE XVI. FIELD EXPERIMENT, CARRINGTON LOAM, FAYETTE COUNTY, MAYNARD FIELD

Plot No.	Treatment	1922 Corn bu. per A.	1923 Corn bu. per A.	1924 Oats bu. per A.	1925 Oats bu. per A.	(1) 1926 Clover tons per A.	(2) 1927 Clover tons per A.
1	Check .....	66.3	45.1	74.6	61.0	0.80	.....
2	Manure .....	70.3	54.3	77.0	68.6	1.02	.....
3	Manure+limestone .....	76.0	59.8	74.6	75.7	1.02	.....
4	Manure+limestone+rock phosphate .....	74.3	69.4	77.8	78.9	1.22	.....
5	Check .....	70.3	53.4	75.1	66.4	0.94	.....
6	Manure+limestone+superphosphate .....	73.4	59.6	86.6	90.4	1.18	.....
7	Manure+limestone+superphosphate+ potassium .....	77.7	63.6	93.6	88.8	1.45	.....
8	Manure+limestone+complete commercial fertilizer .....	76.5	57.3	85.8	90.7	1.17	.....
9	Check .....	66.3	57.0	71.8	73.5	0.95	.....

(1) Clover stand, poor. Fair stand of timothy.

(2) Plots were pastured.

TABLE XVII. FIELD EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY, HUDSON FIELD, SERIES II

Plot No.	Treatment	1918 Corn bu. per A. (1)	1919 Oats bu. per A.	1920 Corn bu. per A. (2)	1921 Corn bu. per A. (3)	1922 Oats bu. per A. (4)	1923 Corn bu. per A. (5)	1924 Oats bu. per A.	1925 Clover and timothy tons per A.	1926 Timothy tons per A. (6)	1927 Corn bu. per A.
1	Check .....	45.8	47.6	53.2	-----	44.8	54.0	40.3	1.43	0.88	45.7
2	Manure .....	49.3	54.7	62.8	-----	53.1	59.6	50.6	1.64	1.16	64.3
3	Manure+lime .....	54.4	59.2	67.4	-----	59.6	65.2	52.2	2.03	1.21	71.2
4	Manure+lime+rock phosphate .....	56.5	64.9	73.3	-----	58.1	61.4	63.4	2.02	1.55	66.3
5	Manure+lime+super- phosphate .....	57.4	62.2	73.3	-----	53.2	59.6	63.7	2.25	1.61	76.3
6	Manure+lime+complete commercial fertilizer .....	58.5	57.5	72.4	-----	62.2	68.4	60.0	2.09	1.64	75.6
7	Check .....	56.9	62.2	44.0	-----	41.4	54.8	50.6	1.84	1.21	57.8
8	Crop residues .....	54.7	62.2	65.2	-----	49.0	53.1	49.5	1.69	1.22	57.8
9	Crop residues+lime .....	57.9	64.6	71.3	-----	62.4	66.7	57.7	2.27	1.66	66.3
10	Crop residues+lime+ rock phosphate .....	62.8	58.1	74.9	-----	59.6	65.7	66.4	2.32	1.70	70.5
11	Crop residues+lime+ superphosphate .....	55.6	55.8	74.9	-----	64.4	62.8	60.9	2.36	1.79	74.1
12	Crop residues+lime+ complete commercial fertilizer .....	52.5	57.5	74.1	-----	71.3	62.8	61.5	2.52	2.03	70.2
13	Check .....	54.5	57.0	71.3	-----	59.7	50.2	48.7	1.94	1.43	55.8

(1) Four tons lime. Hail damaged corn.

(2) Yield on plot 7 evidently an error.

(3) Corn cut and put in silo.

(4) Not very ripe when cut.

(5) Dry season.

(6) High yields on crop residue series due to lower ground and more moisture.

and on the corn in 1927. In every case the manure brought about profitable increases in yields of the general farm crops. The application of lime with the manure increased the yields still more in every season, the beneficial effect being particularly evidenced on the clover and timothy in 1925. Appreciable crop increases were also secured, however, on the corn and oats grown in other seasons.

The application of rock phosphate with the manure and lime increased the yields of crops in most seasons. The beneficial effect was especially evident on the oats in 1919, on the corn in 1920, on the oats in 1924 and on the timothy in 1926. The superphosphate applied with the manure and lime showed slightly larger effects than the rock phosphate in one or two cases, but in general the differences between the yields secured with the two phosphates were slight. Only with the clover and timothy in 1925 and the corn in 1927 were there any great differences in favor of the superphosphate. The complete commercial fertilizer had a larger effect than the phosphates in one or two seasons, but in many cases it showed a smaller beneficial influence than did the superphosphate. The oats in 1922 were increased considerably by the complete commercial fertilizer. The corn in 1923 showed a larger effect from the complete fertilizer than from the phosphate. In several cases the differences were slight.

The crop residues showed little effect on the crop yields, a beneficial effect being evident only in one or two cases. Lime with the crop residues increased the crop yields in every season, bringing about very pronounced gains with the

clover and timothy in 1925 and the timothy in 1926. In several seasons the oats and corn were also increased greatly by the use of lime, the effect being the greatest on the oats in 1922 and on the corn in 1923 and 1927.

The rock phosphate with the crop residues and lime brought about large increases in crop yields in most seasons. In general the gains were not large, but in several seasons they were definite. The superphosphate with the crop residues and lime showed slightly larger effects than the rock phosphate in one or two cases, but in general the yields secured were similar to those secured on the rock phosphate treated plots. The complete commercial fertilizer with the crop residues and lime had larger effects than the phosphates in several cases. Pronounced gains were secured on the oats in 1922, on the clover and timothy in 1925 and on the timothy in 1926. In several other seasons the complete fertilizer showed no greater influence on the yields than did the phosphates.

These results indicate definitely the beneficial effects of applications of manure, lime and a phosphate fertilizer to the Tama silt loam. The results previously discussed are confirmed.

## THE JESUP FIELD

The results secured in the field experiment on the Carrington loam on the Jesup field, Series II, in Black Hawk County, are given in table XVIII.

The beneficial effect of manure on this soil type is evidenced by the increased

TABLE XVIII. FIELD EXPERIMENT, CARRINGTON LOAM, BLACK HAWK COUNTY, JESUP FIELD, SERIES II

Plot No.	Treatment	1918 Oats bu. per A. (1)	1919 Clover tons per A.	1920 Clover and timothy tons per A. (2)	1921 Corn bu. per A.	1922 Corn bu. per A.	1923 Oats bu. per A. (3)	1924 Clover tons per A. (4)	1925 Clover tons per A. (5)	1926 Corn bu. per A. (6)	1927 Corn bu. per A. (7)
1	Check .....	71.9	1.17	0.50	58.7	51.4	31.7	0.92	.....	47.2	28.2
2	Manure .....	71.6	2.08	0.85	72.8	65.6	29.4	1.06	.....	60.5	34.2
3	Manure+lime .....	83.1	1.92	1.20	77.6	71.1	37.3	1.26	.....	60.0	45.9
4	Manure+lime+rock phosphate .....	81.8	1.86	1.15	78.1	73.4	41.8	1.29	.....	72.5	44.9
5	Manure+lime+super- phosphate .....	76.1	2.22	1.12	75.5	73.4	45.3	1.65	.....	73.3	42.9
6	Manure+lime+complete commercial fertilizer .....	77.2	2.80	1.25	78.7	77.6	44.2	1.60	.....	65.3	40.3
7	Check .....	60.8	1.38	0.47	54.0	53.7	34.0	0.58	.....	34.1	17.2
8	Crop residues .....	64.0	1.36	0.52	56.5	56.0	38.3	0.88	.....	.....	.....
9	Crop residues+lime .....	64.9	1.15	0.42	46.4	52.0	36.3	1.15	.....	.....	.....
10	Crop residues+lime+ rock phosphate .....	63.6	1.53	0.42	60.8	60.8	38.7	1.23	.....	.....	.....
11	Crop residues+lime+ superphosphate .....	62.5	1.53	0.60	67.6	62.6	38.3	1.62	.....	.....	.....
12	Crop residues+lime+ complete commercial fertilizer .....	75.7	1.77	0.70	72.8	70.2	38.3	1.67	.....	.....	.....
13	Check .....	67.8	1.20	0.65	60.2	55.4	34.0	1.18	.....	.....	.....

(1) Three and one-half tons lime applied.

(2) Plots 9 and 10 in swale and poorly drained.

(3) Oats thin, dry season.

(4) Plot 7 poor, due to poor drainage; plot 13 high, due to old yard location.

(5) Plots were pastured.

(6) Crop residue plots were left in pasture and not plowed.

(7) Plots 8, 9, 10, 11, 12 and 13 were still in pasture.

crop yields secured in practically all seasons. Large gains resulted from the applications of manure on the clover in 1919, the clover and timothy in 1920 and the corn in 1921, 1922, 1926 and 1927. Lime with the manure proved of value in practically all seasons, in many cases considerable increases in the yields of crops being secured. The oats in 1918, the clover and timothy in 1920, the oats in 1923, the clover in 1924 and the corn in 1927 showed pronounced effects from the addition of the lime.

The application of rock phosphate with the manure and lime increased the crop yields in several seasons, altho in general no large effects were secured. Only with the corn in 1926 were there any large increases from the rock phosphate. In most cases the gains were small, and in one or two seasons no increases at all were secured. The superphosphate with the manure and lime had a larger effect than the rock phosphate in one or two instances, as for example, on the clover in 1919 and 1924. In most seasons small differences between the effects of the two phosphates were noted. The complete commercial fertilizer increased the crop yields slightly more than did the superphosphate in most seasons. In general, however, the differences were not very great, and in one or two cases the complete commercial fertilizer showed less effect than the phosphates.

The crop residues had little effect on the crops grown in most seasons. In one or two cases increases were secured, as on the clover in 1924. Lime with the crop residues increased the crop yields only in one or two seasons. The rock phosphate with the crop residues and lime brought about pronounced increases in the yields of crops in several cases, but in two instances no effects were noted. The superphosphate with the crop residues and lime had a greater effect than the rock phosphate in most seasons. The differences in favor of the superphosphate in some cases were quite pronounced, as on the clover and timothy in 1920 and on the clover in 1924. The complete commercial fertilizer with the crop residues and lime showed a larger effect on the crops grown in practically every season. In some cases considerable increases were secured.

From these results it is apparent that the liberal addition of manure to this soil is very desirable for the best growth of general farm crops. The type is acid in reaction, and the application of lime is essential if the best crops of legumes are to be secured. The addition of a phosphate fertilizer is very desirable on this soil, and in many cases large increases in crop yields are secured from the application of rock phosphate or superphosphate. The use of a complete commercial fertilizer does not seem to be as desirable as the use of a phosphate.

#### THE WAVERLY FIELD

The data secured from the field experiment on the Carrington loam on the Waverly Field No. II, Series I in Bremer County are given in table XIX. The beneficial influence of manure on this soil is shown by the increased crop yields secured in practically every season. In some cases very large gains were noted as for instance, on the clover in 1919, on the corn in 1924 and on the corn in 1927. Lime with manure brought about increased crop yields in practically all seasons. The effect was particularly evidenced on the oats in 1921 and 1925 and on the corn in 1927. The yield on plot 3 in 1919 was evidently abnormal for some reason.

The rock phosphate with the manure and lime increased the crop yields to a very pronounced extent in some seasons but in one or two cases showed no beneficial effect. The clover in 1919 was increased to a large extent and this was true also of the oats in 1925 and the corn in 1927. The superphosphate showed a greater effect than the rock phosphate in most seasons. The differences, however, were generally not large. In one case the superphosphate showed less effect than the rock phosphate and in one instance the results were almost exactly alike. The complete commercial fertilizer had a greater influence than the superphosphate in one or two cases but in general showed a similar effect to that brought about by the superphosphate. Large increases were noted, however, in 1925 from the complete commercial fertilizer.

The crop residues had little effect on the various crops grown. Lime with the residues increased the crop yields in all cases and in some instances very large gains were noted, particularly on the clover in 1919 and 1922 and on the corn in 1927. Large effects were also shown on the oats in 1921 and 1925. The rock phosphate with the crop residues and lime increased the crop yields to a considerable extent in practically every case. The largest influence was noted on the clover crops and on the oats in 1925. The superphosphate with the crop residues and lime had a larger effect than the rock phosphate in practically every

TABLE XIX. FIELD EXPERIMENT, CARRINGTON LOAM, BREMER COUNTY, WAVERLY FIELD, NO. 2, SERIES I

Plot No.	Treatment	1918 Corn bu. per A. (1)	1919 Clover tons per A.	1920 Corn bu. per A. (2)	1921 Oats bu. per A. (3)	1922 Clover tons per A. (4)	1923 Corn bu. per A. (5)	1924 Corn bu. per A. (6)	1925 Oats bu. per A. (7)	1926 Clover tons per A. (8)	1927 Corn bu. per A.
1	Check .....	42.8	1.50	47.8	25.7	2.22	.....	11.0	.....	.....	40.4
2	Manure .....	61.0	1.75	56.5	34.3	2.20	.....	24.7	63.9	.....	53.3
3	Manure+lime .....	64.9	1.10	57.5	50.6	2.32	.....	30.4	77.7	.....	65.8
4	Manure+lime+rock phosphate .....	65.5	2.60	58.0	40.3	2.10	.....	34.3	87.8	.....	63.4
5	Manure+lime+complete commercial fertilizer .....	72.1	2.35	44.0	35.7	2.78	.....	42.1	103.3	.....	62.9
6	Manure+lime+super- phosphate .....	67.2	2.85	47.0	42.0	2.90	.....	38.2	89.3	.....	67.3
7	Check .....	55.1	1.55	36.6	30.6	1.76	.....	19.2	59.9	.....	36.7
8	Crop residues .....	49.6	1.05	39.6	20.3	1.24	.....	18.8	51.7	.....	38.6
9	Crop residues+lime .....	66.2	1.50	40.8	30.4	1.84	.....	20.3	62.1	.....	55.5
10	Crop residues+lime+ rock phosphate .....	70.0	1.75	41.6	40.6	2.16	.....	20.5	85.3	.....	59.8
11	Crop residues+lime+ superphosphate .....	88.2	2.55	43.3	38.4	2.70	.....	23.1	86.9	.....	61.4
12	Crop residues+lime+ complete commercial fertilizer .....	88.6	2.10	45.8	46.0	2.70	.....	22.4	86.5	.....	51.6
13	Check .....	79.7	1.55	35.1	26.7	1.48	.....	16.3	53.4	.....	33.4

(1) Six tons lime, fall 1917.

(2) Soybeans planted in corn, both crops poor. Wet spring injured plots in center series. Plots 5 and 6 and crop residue plots weedy.

(3) Plot 3 too high, many morning glory vines on plot.

(4) Stand uneven on 2 and 4.

(5) No crop yields secured owing to drought.

(6) Crop damaged by frost—phosphate plots showed more maturity.

(7) Barley seeded by mistake on plot 1. Unable to account for high yield on plot 5.

(8) Field pastured—no results taken.

TABLE XX. FIELD EXPERIMENT, CARRINGTON LOAM, BREMER COUNTY, WAVERLY FIELD, NO. 2, SERIES II

Plot No.	Treatment	1918 Corn bu. per A. (1)	1919 Oats bu. per A.	1920 Clover tons Per A. (2)	1921 Clover and timothy tons per A.	1922 Corn bu. per A. (3)	1923 Corn bu. per A. (4)	1924 Oats bu. per A. (5)	1925 Sweet Clover tons per A.	1926 Alfalfa tons per A. (6)	1927 Alfalfa tons per A. (7)
1	Check .....	38.5	39.8	0.47	1.03	39.4	25.0	42.8	0.39	.....	0.51
2	Manure .....	54.0	49.3	0.67	1.30	55.7	40.2	49.7	0.45	0.76	1.46
3	Manure+lime .....	56.8	61.9	1.36	1.87	62.3	57.0	66.4	2.66	1.28	2.52
4	Manure+lime+rock phosphate .....	57.2	46.4	1.66	1.98	63.1	62.0	64.9	2.72	1.61	3.19
5	Manure+lime+super- phosphate .....	60.5	57.8	2.05	2.19	64.0	60.7	75.8	3.03	1.65	3.18
6	Manure+lime+complete commercial fertilizer .....	61.3	61.9	1.99	2.47	62.9	63.0	65.3	3.03	1.35	3.12
7	Check .....	48.7	35.4	0.84	1.17	45.7	34.2	42.5	0.62	0.67	0.96
8	Crop residues .....	46.4	39.4	0.67	1.09	41.4	34.0	48.3	0.62	0.69	0.79
9	Crop residues+lime .....	50.0	48.3	0.87	1.26	50.6	45.2	55.5	2.93	1.10	1.72
10	Crop residues+lime+ rock phosphate .....	56.7	40.8	1.14	1.44	52.0	46.5	74.7	3.02	1.11	2.04
11	Crop residues+lime+ superphosphate .....	48.7	47.3	1.11	1.63	51.4	47.5	70.9	3.02	1.36	2.21
12	Crop residues+lime+ complete commercial fertilizer .....	42.7	53.5	1.32	2.10	60.8	50.7	51.2	2.96	1.31	2.55
13	Check .....	33.4	32.9	0.33	0.87	34.8	43.2	37.8	0.45	0.69	0.36

- (1) Six tons lime, fall 1917. Heavy rains washed 11, 12 and 13 badly.
- (2) Plots 1 and 2 poorer in fertility than other plots.
- (3) Dry season.
- (4) Plot 13 high, probably due to manure application made thru error.
- (5) Low yield on plot 12 due to part of crop lost in threshing.
- (6) Grasshoppers destroyed the crop on plot 1 and damaged west side of all plots.
- (7) Two cuttings. First cutting mostly timothy on plots 1 and 13. Timothy seeded in 1926 to thicken stand.

season. In some seasons the gains were pronounced, as on the clover in 1919 and 1922. In other cases the differences were not large. The complete commercial fertilizer with the crop residues and lime had about the same effect, as did the superphosphate, showing a slightly greater influence in some cases and a smaller effect in others.

The results secured on the Carrington loam on the Waverly field No. II, Series II, in Bremer County, are given in table XX. Here again the beneficial influence of manure on this soil is evidenced by the great increases in crop yields secured in practically every season. The clover in 1920 and 1921, the corn in 1922 and 1923 and the alfalfa in 1927 showed the largest influence from the use of manure. The application of lime with the manure brought about distinct gains in crop yields in every season. In some cases the gains were very large, as on the clover in 1920 and 1921, the sweet clover in 1925, the corn in 1923, the oats in 1924 and the alfalfa in 1926 and 1927.

The rock phosphate with the manure and lime had a beneficial effect on the crop yields in most seasons. The differences, however, were small and in some cases no gains were noted. The superphosphate with the manure and lime increased the yields considerably in most seasons, the largest effect being noted on the clover and alfalfa, altho there also was a large effect on the oats in 1924. The complete commercial fertilizer showed a somewhat greater effect than the

superphosphate in some cases but in several instances did not bring about as large increases.

The crop residues had little effect on the crop yields, small increases being noted only in one or two cases. Lime with the residues increased the crop yields in a very pronounced way, in some cases bringing about large increases, as, for instance, on the sweet clover in 1925 and on the alfalfa in 1926 and 1927. The rock phosphate with the crop residues and lime increased the yields in most cases, the differences being considerable on the clover crops and on the oats in 1924. The superphosphate with the crop residues and lime showed a larger effect than the rock phosphate in one or two cases, but the differences were not large and in general the two phosphates seemed to give about the same returns. The complete commercial fertilizer showed a larger effect than the superphosphate in some cases, particularly on the clover and timothy in 1921 and on the alfalfa in 1927, but in other instances there were smaller effects from the complete fertilizer.

These results as a whole serve to confirm the conclusions from the experiments on the same soil type from Black Hawk County.

## THE SPRINGVILLE FIELD

The results secured on the Carrington silt loam on the Springville Field, Series I, in Linn County are given in table XXI. Beneficial effects of manure on this soil are definitely shown by these results. Considerable increases in crop yields

TABLE XXI. FIELD EXPERIMENT, CARRINGTON SILT LOAM, LINN COUNTY, SPRINGVILLE FIELD, SERIES I

Plot No.	Treatment	1918 Clover tons per A. (1)	1919 Corn bu. per A. (2)	1920 Corn bu. per A. (3)	1921 Oats bu. per A.	1922 Clover tons per A. (4)	1923 Corn bu. per A. (5)	1924 Corn bu. per A. (6)	1925 Oats bu. per A.	1926 Corn bu. per A.	1927 Oats bu. per A.
1	Check .....	2.25	58.6	46.5	44.8	1.37	40.2	.....	53.9	41.6	21.5
2	Manure+lime .....	2.47	64.8	63.3	36.4	1.47	51.2	.....	72.4	49.3	33.8
3	Manure .....	2.40	63.7	51.1	46.9	1.35	55.9	.....	57.4	46.4	31.0
4	Manure+lime+rock phosphate .....	2.70	60.8	66.1	42.8	2.02	60.2	.....	71.6	50.4	45.5
5	Manure+lime+super- phosphate .....	2.70	67.1	60.8	46.3	2.14	59.7	.....	68.6	47.4	41.9
6	Manure+lime+complete commercial fertilizer .....	2.70	64.5	61.0	49.2	1.99	60.7	.....	74.1	47.4	37.8
7	Check .....	1.65	60.0	51.9	36.9	1.35	40.0	.....	43.6	34.4	35.1
8	Crop residues .....	2.05	62.5	55.0	42.8	1.40	46.2	.....	47.4	37.8	36.8
9	Crop residues+lime .....	2.02	49.4	59.6	38.9	1.56	44.2	.....	62.1	38.6	41.9
10	Crop residues+lime+ rock phosphate .....	2.16	55.7	58.5	43.6	1.98	54.4	.....	64.8	36.8	52.0
11	Crop residues+lime+ superphosphate .....	2.47	55.4	58.5	48.4	2.10	43.5	.....	62.2	37.0	48.5
12	Crop residues+lime+ complete commercial fertilizer .....	2.19	33.1	57.3	37.8	2.04	44.7	.....	72.4	38.6	56.6
13	Check .....	1.80	45.7	41.1	36.0	1.51	36.1	.....	45.3	30.9	45.5

(1) Three and one-half tons lime, fall 1917.

(2) Plots 10, 11, 12 and 13 on low ground, poor stand.

(3) Plot 2, small ditch, abnormal yield.

(4) Clover down badly on 5 and 6, and 11 and 12; only 85% could be cut.

(5) Season dry.

(6) Field was replanted and corn did not mature; no result taken.

were secured from the use of manure in practically all cases. In some seasons the crops were increased to a large extent, as was the case with the corn in 1923. The application of lime along with the manure increased the crop yields in most seasons. In several cases large benefits were secured from the use of this material, as, on the corn in 1920 and on the oats in 1925.

The rock phosphate with the manure and lime showed very definite increases in crop yields in practically all seasons. In some cases the gains were striking, as, for example, on the clover in 1922, on the corn in 1923 and on the oats in 1927. The superphosphate with the manure and lime gave larger increases than the rock phosphate in several cases but in others the rock phosphate proved somewhat superior. The differences were not great, however, in any instance. The complete commercial fertilizer showed slightly smaller yields than the superphosphate in some seasons but in other cases had a somewhat larger effect.

The crop residues brought about increases in the yields in most seasons. Lime with the residues had a beneficial effect in several cases, the largest influence being secured on the oats in 1925. Rock phosphate with the crop residues and lime had a beneficial effect on the crop yields in all but two cases. In some seasons the influence was very large, as, for example, on the clover in 1922, on the corn in 1923 and on the oats in 1927. The superphosphate with the crop residues and lime showed a larger effect than the rock phosphate in several seasons, but in other cases the influence was very similar to that secured from the rock phosphate. In one case there was a very pronounced difference in favor of the rock phosphate. The complete commercial fertilizer showed a smaller effect than the superphosphate in most seasons, and in three cases where a larger influence was exerted the differences were not large enough to be of significance.

From these results it is apparent that manure is of great value on the Carrington silt loam and liberal additions of this material should be made. The type is acid in reaction, and the use of lime is, therefore, very desirable for the best growth of legumes. Beneficial effects will also be secured from the use of lime on other general farm crops. Applications of a phosphate fertilizer are to be recommended. Whether superphosphate or rock phosphate should be employed cannot be definitely stated at the present time.

#### THE OSAGE FIELD

The results secured on the Carrington silt loam on the Osage Field in Mitchell County are given in table XXII. The application of manure to this soil type proved valuable in increasing crop yields. Only in one season was there no considerable increase in the crops grown. In some cases very large gains were noted, as, for example, on the oats in 1920, on the clover in 1921, on the corn in 1922, on the clover and timothy in 1925 and on the corn in 1926. The use of lime with manure gave further increases in the yields of crops in most seasons. In one or two cases no increases were noted. In general, however, the gains were pronounced. The corn in 1919 and in 1927 was benefited to a considerable extent. The clover in 1921, the corn in 1923 and the clover and timothy in 1925 were materially increased by the use of the lime.

The application of rock phosphate with the manure and lime proved of value on practically all the crops grown. Only in one case was there no evidence of

TABLE XXII. FIELD EXPERIMENT, CARRINGTON SILT LOAM, MITCHELL COUNTY, OSAGE FIELD, SERIES I

Plot No.	Treatment	1918 Corn bu. per A. (1)	1919 Corn bu. per A.	1920 Oats bu. per A. (2)	1921 Clover tons per A. (3)	1922 Corn bu. per A. (4)	1923 Corn bu. per A. (5)	1924 Oats bu. per A. (6)	1925 Clover and Timothy tons per A. (7)	1926 Corn bu. per A.	1927 Corn bu. per A. (8)
1	Check .....	46.5	55.8	34.6	1.09	58.8	42.3	72.4	0.97	37.3	25.9
2	Manure .....	52.8	60.0	60.3	1.55	68.0	50.8	71.0	1.25	51.4	26.6
3	Manure+lime .....	52.8	70.0	56.3	1.98	68.0	64.1	82.8	1.64	56.0	41.4
4	Manure+lime+rock phosphate .....	54.8	72.0	61.2	1.94	74.3	70.7	86.5	1.68	57.0	43.5
5	Manure+lime+super- phosphate .....	56.4	77.0	61.2	1.82	76.0	70.7	98.0	1.90	55.7	40.9
6	Manure+lime+complete commercial fertilizer .....	44.5	79.0	67.3	1.63	72.3	70.2	102.9	1.92	60.8	38.8
7	Check .....	38.8	67.0	59.8	1.48	50.0	53.7	74.3	1.12	46.6	25.5
8	Crop residues .....	37.7	65.0	55.0	1.55	51.4	52.0	71.8	1.14	41.3	25.9
9	Crop residues+lime .....	39.4	74.0	50.3	1.55	58.3	65.2	81.6	1.63	52.0	38.0
10	Crop residues+lime+ rock phosphate .....	47.4	75.0	61.8	1.55	57.7	64.4	90.3	1.94	52.5	25.6
11	Crop residues+lime+ superphosphate .....	44.2	73.0	59.8	1.44	62.3	64.9	78.4	2.07	51.2	35.9
12	Crop residues+lime+ complete commercial fertilizer .....	48.8	78.0	67.3	1.79	65.5	69.9	87.1	1.55	50.9	37.3
13	Check .....	39.7	67.0	53.1	1.59	52.3	53.2	75.6	0.88	44.0	30.4

- (1) Four tons lime applied.
- (2) Plot 1, low yield, oats down badly; four tons lime applied in September.
- (3) Clover pastured heavily in spring.
- (4) Corn down badly on checks and crop residue plots.
- (5) Dry weather reduced yields.
- (6) Poor stand on plot 11 due to pocket gophers.
- (7) Clover mostly killed out in spring due to ice sheet; good stand of timothy.
- (8) Plot 10 damaged by gophers.

an increased crop yield. The superphosphate with the manure and lime showed better results than the rock phosphate in most cases. The oats in 1924 and the clover and timothy in 1925 showed much larger effects from the superphosphate than from the rock phosphate. The complete commercial fertilizer with the manure and lime showed somewhat larger effects than the superphosphate in several seasons. In general, however, the differences were small, and in one or two cases the complete fertilizer did not give as large increases on the crops grown as did the superphosphate.

The crop residues showed little effect on the various crops grown. Lime with the crop residues increased the yields in practically all seasons. In some instances very large gains were noted, as, for example, on the corn in 1919, on the corn in 1923, on the oats in 1924, on the clover and timothy in 1925, on the corn in 1926 and on the corn in 1927.

The rock phosphate with the crop residues and lime showed a beneficial effect on the crops grown in most cases. In one or two instances large increases were secured, as, on the oats in 1920, on the oats in 1924 and on the clover and timothy in 1925.

The clover in 1921 and the corn in 1922, 1923 and 1927 showed no beneficial effects from the rock phosphate. The superphosphate with the crop residues and lime showed a slightly greater effect than did the rock phosphate in only

three seasons. In most cases the benefits were less pronounced than from the rock phosphate, altho, generally, the differences were small. The complete commercial fertilizer had a larger effect than the phosphates in most seasons, but the differences were not very great.

These results, as a whole, confirm the conclusions drawn from the experiment on the same type in Linn County.

### **THE NEEDS OF WINNESHIEK COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS**

The laboratory, greenhouse and field experiments which have been discussed earlier in this report have given rather definite indications of the needs of some of the more important soils in the county. Certain general recommendations may, therefore, be given for the handling of the soils of the county, and definite suggestions can be offered regarding the best treatments for some of the soil types. Specific treatments for the various soils will be given under the discussion of the individual soil types in a later section. General principles for the management of the soils will be considered here.

The recommendations given here are based upon the tests conducted in the laboratory and greenhouse, in the field in this county, on similar soil types in other counties and also upon the experiences of many farmers. Only those suggestions are offered which have been found to be of considerable value by practical experience. Any of the recommendations made may be put into effect on any farm.

In several instances it is suggested that tests be carried out on individual farms. Many farmers are already carrying out tests on their own farms at the present time and are securing results which are of much value to themselves and to their neighbors who are located on the same soils. The Soils Section of the Iowa Agricultural Experiment Station\* will gladly aid farmers who wish to conduct tests on their own soils.

### **LIMING**

All the soils of Winneshiek County, except the Cass types on the bottoms and the Dubuque silt loam on the residual uplands, are acid in reaction and in need of lime. In practically all cases where the surface soils are acid, the lower soil layers are also acid, and hence the need of lime is shown not only by the tests made on the surface soils but also by the tests of the subsurface soils and subsoils.

The limestone requirements of the various soil types are given earlier in this report. These data, however, merely indicate the lime needs of the individual soils. There is a wide variation in the lime requirements of soils of the same type under different conditions or even in different fields. It is always necessary, therefore, that the soil in any field be tested for lime needs before any application is made. Only by such a test will it be possible to apply the proper amount of lime and secure the best and most profitable results from the application. Farmers may test their own soils for acidity and need for lime, but it will generally be more satisfactory if they will send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge.

\* See Circ. 97 of the Iowa Agricultural Experiment Station.

The experimental work with lime has shown definite beneficial effects from its application. The results discussed earlier in this report indicated the large increases in crop yields which follow the use of lime on acid soils in this county. Not only are the yields of crops like legumes, which are very sensitive to acidity, increased enormously, but the yields of other general farm crops are also increased; often to a very profitable extent. The experiences of many farmers confirm the results of these tests. It is a commonly accepted fact that the best crop growth will not be secured on acid soils, and the value of applications of lime is well known. All the soils of Winneshiek County, except the Cass and Dubuque types, should be tested for lime needs, and lime should be applied as needed if the most satisfactory crop yields are to be secured. Tests should be made at least once in a four-year rotation, preceding the legume crop, in order that the reaction of the soil may be the best for the legume crop. One application of lime will not serve for all time. The soils must be tested regularly and lime must be applied to keep the reaction of the soil basic. Further information regarding the use of lime on soils, the losses by leaching and other points connected with liming are given in Extension Bulletin No. 105 of the Iowa Agricultural Extension Service.

### MANURING

The most extensive upland soils of Winneshiek County are fairly well supplied with organic matter. Many of them are dark or even black in color, indicating a good supply of organic matter and nitrogen. In some of the minor sandy types, however, the color is lighter, and the supply of organic matter is not so good. On these soils the addition of organic matter is necessary at the present time, if the soil is to be made properly productive. The Lindley loam and the shallow phase of this type, the Carrington fine sandy loam and the Dickinson sandy loam on the drift uplands, the Clinton silt loam, the Fayette silt loam and the Fayette fine sand on the loess uplands, the Buckner, O'Neill and Plainfield types on the terraces, the Cass types on the bottoms, and the Boone fine sandy loam on the residual upland will all respond to applications of organic matter. They are not extremely low in this constituent, but there is need for the addition of organic matter. On the other types in the county the use of organic matter is necessary, occasionally, if the supply is to be kept up. Even tho the soils are now dark in color and apparently well supplied with organic matter, it is necessary that additions of organic matter be made regularly, or eventually a deficiency will occur.

Farm manure is the most valuable fertilizing material available for use on the soils of this county and it is the chief source of organic matter. Its application will be particularly valuable on the light colored, sandy textured types, altho large increases are also secured from its use on the dark colored, heavier textured soils. On the former the applications may be heavier, while on the latter types smaller amounts of manure should be employed.

The data given earlier in this report have shown the large value of manure on some of the main types in the county. The Tama silt loam, the Carrington loam, the Carrington silt loam and the Fayette silt loam have all given a definitely profitable response to the addition of manure. The effects from the use of

manure would undoubtedly be even more striking in the case of the other soil types in the county.

On the livestock farm the amount of manure produced is often inadequate to supply the needs of all the soils and in such cases some other means of supplying organic matter must be employed. On the grain farm little or no manure is produced, and some material is needed as a substitute for farm manure. In both cases, the turning under of leguminous crops as green manures is a very desirable practice. Green manuring with legumes adds large amounts of organic matter and also adds large quantities of nitrogen to the soil if the legumes are well inoculated, as they should be when properly grown. Unquestionably many of the soils in Winneshiek County would respond profitably to green manuring, and the practice is to be recommended, especially on the grain farm and on the lighter-colored, coarser-textured soil types. Wherever the soil is low in organic matter and nitrogen, which is indicated by a light color, green manuring with a legume will be of value. Green manuring, as a supplement to farm manure or as a substitute for it, is a good practice. Care should always be exercised, however, when green manuring is practiced, as undesirable results may occur if the conditions in the soil are not right for the proper decomposition of the green material.

The utilization of all crop residues produced on the farm also aids materially in maintaining the supply of organic matter in the soil.

#### THE USE OF COMMERCIAL FERTILIZERS

The analyses of the soils of the county, which have been discussed earlier in this report, show no large supply of phosphorus in any of the types. In most cases the phosphorus content is so low as to indicate a probable deficiency in available phosphorus now or in the near future. There is a strong probability that phosphorus fertilizers would have large value in many cases at the present time.

The data obtained in the greenhouse and field tests which have been reported show a definite benefit from rock phosphate and superphosphate on some of the more extensively developed types. The Tama silt loam, the Carrington silt loam, the Carrington loam and the Fayette silt loam have responded very profitably to the application of a phosphate fertilizer. In some cases the superphosphate has seemed preferable, while in other instances the rock phosphate has given just as satisfactory results.

Rock phosphate is usually applied at the rate of one ton per acre once in the four-year rotation. It may possibly be used, however, with just as great effects at the rate of 1,000 pounds per acre once in four years. The superphosphate is applied at the rate of 150 pounds per acre annually or three years out of four, in the four-year rotation. The superphosphate is more expensive than the rock phosphate but it is applied in smaller amounts. It supplies the element phosphorus in a form readily available to the plant, while the rock phosphate carries the element in a form from which it must be changed into an available form. Hence many times, the rock phosphate does not show its greatest effect until the second year after application.

Definite recommendations cannot yet be made regarding the relative value of

the two phosphates on the various soil types. It is recommended and urged, therefore, that farmers test both materials on their own soils and thus determine for their particular conditions which will be the more desirable to use. Simple tests may be carried out on any farm. Directions for such tests are given in Circular 97 of the Iowa Agricultural Experiment Station.

The soils of Winneshiek County seem to be fairly well supplied with nitrogen, but there are some cases where the content of this element is low. Wherever nitrogen is not present in sufficient amount to meet the needs of crops, the addition of some material supplying nitrogen is necessary. In all cases, however, it is necessary that some nitrogen fertilizer be used at regular intervals, if the supply of nitrogen is to be kept up. The growth of crops removes some nitrogen and there is a constant loss in drainage water. Additions must be made or the nitrogen supply will very quickly become inadequate for the best crop yields. The use of a nitrogenous fertilizer is especially needed at the present time on the light-colored, coarse-textured soils.

Green manuring with legumes is the best means of supplying nitrogen to the land. When well-inoculated, legumes take a large part of their nitrogen from the atmosphere and when the crop is turned under in the soil there is a corresponding increase in the nitrogen content of the soil. The practice of green manuring may be of large value on many of the soils in Winneshiek County at the present time. It has a double value, as has been noted, in that it also supplies organic matter as well as nitrogen.

The proper preservation and application of farm manure will aid materially in maintaining the supply of nitrogen in the soil, as the manure returns to the land a large part of the nitrogen removed by the crops. On the livestock farm, then, manure may be considered the most important nitrogenous fertilizer. Manure also supplies organic matter and certain plant food constituents and stimulates the production of available plant food in the soil. On the grain farm the use of legumes as green manures is the chief means of building up and keeping up the nitrogen supply. Crop residues also supply nitrogen and in all types of farming the proper utilization of all the residues will aid materially in maintaining the supply of nitrogen.

The use of commercial nitrogenous fertilizers is probably unnecessary on the soils of Winneshiek County at the present time. The proper use of farm manure, crop residues and legumes as green manures should supply sufficient nitrogen. Small amounts of commercial nitrogen carriers may be used as top dressings in certain cases with profitable results. Tests of such materials should always be carried out, however, before extensive applications are made.

According to previous analyses, the amount of potassium present in the soils of the county should be sufficient to supply the needs of crops for many years to come. Whether or not there is an adequate production of available potassium to keep crops supplied depends upon the soil conditions. If the land is well drained and properly cultivated, if it is manured or green manured and if it is well supplied with lime and is not acid in reaction, the production of available potassium should be rapid enough to meet the requirements of crops. All the farming operations which improve the soil will, therefore, tend to increase the production of available potassium. Possibly, potassium fertilizers may be of

value on some of the soils, if the processes which lead to the making of potassium available are not proceeding properly. Small amounts of a commercial potassium carrier, as a top dressing, may yield profitable results. Tests of these fertilizers should always be carried out on a small scale before any extensive application is made.

Increased yields have been secured in some cases with a complete commercial fertilizer. The tests described earlier in this report have shown the beneficial effects of a standard brand of a complete fertilizer on some of the more extensive soil types occurring in this county. In general, however, the phosphates gave as good results and, inasmuch as they are much less expensive, it seems that they would be more desirable for general use. Tests of any complete fertilizer should be carried out in comparison with superphosphate before the material is used extensively. It must bring about much larger increases in crop yields than the superphosphate if it is to be as profitable for use. There is no objection to the application of a complete fertilizer. It is simply a matter of the profit secured; thus far, greater profits have generally been obtained from the superphosphate when applied to general farm crops. Farmers who are interested are urged to test any complete fertilizer under their own conditions and thus determine whether or not it can be applied with more profit than the superphosphate.

#### **DRAINAGE**

As has been noted previously, the natural drainage system of the county is adequate in most cases, and the soils of the county, as a whole, are fairly well drained. In some areas, however, the land is not properly drained naturally. Along some of the smaller streams, where the valleys are shallow and the topography of the land is gently rolling to flat, and at the heads of drainageways, there is apt to be a rather poorly drained condition. In some soils, too, the subsoil is rather heavy and impervious, and the drainage of such types is restricted. Installation of tile is desirable, in many cases, under such conditions. In all parts of the county, where drainage conditions are not entirely satisfactory, tiling will generally be of distinct value.

The Clyde silty clay loam on the drift uplands is especially in need of drainage. It is the outstanding type in the county which is naturally poorly drained. There are also areas in the Carrington loam and in the Carrington silt loam where drainage would be of value. On the terraces the Bremer soils are particularly in need of drainage, and on the bottoms the Wabash soils are poorly drained. In the latter case the soils must be protected from overflow if they are to be satisfactorily cropped, which must be done before drainage will be of any large value.

Whenever a soil is too wet, good crop yields will not be secured. The first treatment needed on some of the soils of Winneshiek County is the installation of tile in order to bring about adequate drainage. No fertilizing material will be of any value if the soil is too wet. The expense of tiling may be considerable, but farmers will find that the increased crop yields will soon more than pay for the installation. In some instances tiling will mean the difference between a crop failure and a profitable crop.

## THE ROTATION OF CROPS

Many experiments and much experience have demonstrated conclusively that the continuous growing of one crop will quickly reduce the fertility of the soil. Farmers who follow this practice soon note a gradual decrease in the yields of crops, and finally the yields will become so low as to be unprofitable. In spite of the general knowledge of this fact, the large money value of some crop often leads farmers to follow this very undesirable practice of continuous cropping.

Data have been secured which show definitely that the rotation of crops is a much more profitable practice than continuous cropping, even if crops of lower money value are included in the rotation. This is due to the fact that under a rotation system crop yields are not decreased as rapidly as when one crop is grown continuously. It has also been shown that it is possible to maintain the fertility of a soil much more readily under a rotation system.

While no rotation experiments have been carried out in Winneshiek County, some general recommendations may be given regarding rotations which will probably prove of most value in this county. From among the rotations listed below some one may be chosen for use in this county, or to serve as a basis upon which a rotation may be worked out for any individual farm conditions.

### 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 for 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 with 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 sweet clover)

*Third year*—Sweet clover (the clover may be mixed clovers and used largely as pasture and green manure.) (This may be changed to a two-year rotation by plowing under the sweet clover the following spring for corn.)

*First year*—Wheat (with clover)

*Second year*—Corn

*Third year*—Cowpeas or soybeans

**THE PREVENTION OF EROSION**

Erosion is the carrying away of the surface soil by the free movement of water over the surface of the land, known as sheet erosion, or the washing away of the soil with the formation of gullies, gulches or ravines.

Erosion occurs to some extent in the soils of Winneshiek County. On the drift uplands the Lindley loam is subject to considerable washing; the shallow phase of the type having been formed by the washing away of the surface soil. Some of the other types on the uplands are also badly washed in some areas. Wherever erosion occurs, some means to prevent and control it should be adopted.

The methods to be followed for the control and prevention of erosion in Iowa depend upon the type of erosion. Erosion due to "dead furrows" may be controlled by "plowing in," by "staking in" or by the use of earth dams.

Small gullies may be filled by the "staking in" operation, by the use of straw dams, earth dams, Christopher or Dickey dams, Adams dams, stone dams, rubbish dams, woven wire dams, or concrete dams. They may be prevented from occurring by thoro drainage or by the use of sod strips. Large gullies are similarly filled or prevented from occurring. Erosion in bottomlands may be prevented by straightening the streams, by tiling and by planting trees up the drainage channels. Hillside erosion is controlled by the use of organic matter, by growing cover crops, by contour discing, by terracing, by deep plowing and by the use of sod strips.\*

**INDIVIDUAL SOIL TYPES IN WINNESHIEK COUNTY\*\* \*\*\***

There are 32 individual soil types in Winneshiek County and these, with the shallow phase Lindley loam and the areas of muck and rough stony land, make a total of 35 separate soil areas. They are divided into five groups on the basis of their origin and location, namely: drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils.

\* See Bulletin 183. Soil Erosion in Iowa, Iowa Agricultural Experiment Station and Extension Service Bulletins 93, 94, 95, 96, Agr. Extension Service, Iowa State College.

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

\*\*\* Winneshiek County adjoins Fayette County on the south; in certain small areas the soils of these two counties do not seem to agree. These apparent discrepancies are due to changes in correlation resulting from a fuller knowledge of the soils of the state, as where the Thurston sandy loam in Fayette County is changed to Dickinson sandy loam in Winneshiek County and the Carrington fine sandy loam to Cass fine sandy loam. The Plainfield loam of Fayette County has not been extended into this county on account of its very small area but is combined with the Plainfield fine sandy loam.



Fig. 17. A rough area in Winneshiek County gullied by erosion.

### DRIFT SOILS

There are seven drift soils in the county, classified in the Carrington, Clyde and Dickinson series. Together they cover 21.1 percent of the total area of the county.

#### CARRINGTON LOAM (1)

The Carrington loam is the most extensively developed drift soil and the third largest individual soil type; it covers 12.1 percent of the total area of the county and occurs in extensive areas on the upland in the western townships. This soil is most largely developed west of the Turkey River and south of Walnut Creek in Madison and Lincoln Townships and covers practically the entire upland area in Jackson Township. It is also largely developed in Washington, Orleans and Sumner Townships. The type is found developed only on the western side of the county, marking the boundary of the Iowan drift soil area. The line separating this drift soil from the loess types to the east extends roughly from the point where Turkey River leaves the county on the southern county line north along the river to Ft. Atkinson, then northward to Conover and northeastward to the southwest corner of Decorah Township, then in a general northwestward direction toward Kendallville. In addition to the large development of the type mentioned in the extreme western townships of the county, there are small isolated areas one mile north of Festina, a mile and a half east of Ft. Atkinson and a half-mile southwest of Conover.

The surface soil of the Carrington loam is a mellow dark grayish-brown loam extending to a depth of 14 inches. At this point the subsoil consisting of a brown to yellowish-brown silty clay loam is encountered. At 20 inches the subsoil becomes a lighter yellowish-brown silty clay to clay loam. There is considerable fine sand and some coarse sand and gravel thruout various parts of the profile. In local areas the texture of the type varies considerably, ranging

from a loam to almost a sandy loam. Where the type occurs adjacent to the areas of Clyde silty clay loam the texture is somewhat more sandy. Pockets of yellowish-brown gravelly sand or sandy gravel occur on the slopes of some of the hills. The substratum, 4 or 5 feet below the surface, is a yellowish-brown mixture of ground limestone and sandstone with fragments of shale and granite. Granite quartz-like boulders occur on the surface and thru the soil section. Calcareous material is not present in the upper 3 feet of the soil section. The type reacts strongly acid in the surface.

In topography the Carrington loam is gently undulating, the surface of the type being characterized by gently rounded hills with long slopes and shallow, almost slough-like drainage lines. The natural drainage of the type is good.

Practically all of the soil is now under cultivation, general farm crops being grown. Along the streams and in a few of the rougher areas there is a scattered growth of timber. A few groves of trees used for windbreaks are found around farmsteads. Corn is the principal crop grown; yields amounting to from 30 to 65 bushels per acre and averaging around 37 bushels. Some oats are grown with average yields of about 32 bushels per acre. Wheat is not an important crop. Timothy and clover is the principal hay crop, yielding from 1 to 2 tons per acre. Potatoes are grown yielding around 100 bushels per acre. Alfalfa and soybeans are found on small areas.

The Carrington loam is naturally a rather productive soil. Large increases in crop yields may be secured, however, thru proper fertilization and management. The type will respond to applications of farm manure which should be added in as large amounts as possible. The type is acid in reaction and additions of lime are very necessary for the best growth of general farm crops, particularly for the maximum growth of legumes such as clover and alfalfa. The type should always be tested for lime needs and lime should be added as needed. Applications of a phosphate fertilizer have been found to bring about large crop in-



Fig. 18. A Carrington loam topography in Winneshiek County.

creases on this soil, and the use of superphosphate or rock phosphate is strongly recommended. By the proper application of farm manure and the use of lime to remedy acidity and the application of a phosphate fertilizer, crop yields may be largely increased and the fertility of this soil may be maintained at a high point. The experiments discussed earlier in this report indicate definitely the large value of applications of these fertilizing materials to this soil type.

#### CARRINGTON SILT LOAM (83)

The Carrington silt loam is the second largest drift soil and the seventh most extensively developed soil. It covers 3.5 percent of the total area of the county, and is developed only in the western part, in association with the Carrington loam of the drift uplands. The largest areas of the type are found in Lincoln, Buxton and Orleans Townships, and in scattered areas north and east of the Turkey River between the Turkey and Upper Iowa Rivers there are a few small scattered areas about a mile west of Turkey River. The largest individual areas of the type are found in the southwestern corner of Buxton Township in the southwestern corner of Orleans Township, southwest of Plymouth Rock and extending north of Conover in Calmar Township.

The surface soil of the Carrington silt loam is a dark-brown mellow silt loam extending to a depth of 12 inches. It contains considerable fine sand. The subsoil is a brown to yellowish-brown silty clay loam changing at a depth of 24 inches to a yellowish-brown silty clay to clay loam with some faint yellowish-brown mottlings below 30 inches. The subsoil contains much fine sand and some gravel. In the areas of the type north of Walnut Creek the soil is more silty in nature but contains less sand. Along the stream slopes there is a larger proportion of sand present. Where it adjoins areas of the Tama silt loam the establishing of boundaries between these soil types has been necessarily rather arbitrary. There is a gradual change from the Carrington silt loam into the Tama silt loam.

The type is gently rolling to undulating in topography and drainage is good. Most of the soil is under cultivation and general farm crops are grown. Timber is found on some of the steeper slopes adjacent to the stream courses. Yields of general farm crops are satisfactory and compare favorably with the yields secured on the Tama silt loam. Corn yields range from 30 to 60 bushels per acre; oats from 30 to 65 bushels per acre, with an average around 35 to 40 bushels; and timothy and clover hay yield 1½ tons per acre.

Crop yields may be increased on this soil by the adoption of proper methods of treatment. The application of farm manure is of large value and liberal amounts of this material should be applied. The type is acid in reaction and additions of lime are very necessary for the best growth of general farm crops, especially for the legume crops of the rotation. The addition of phosphate fertilizers will undoubtedly increase crop yields on this soil. Experiments which have been discussed earlier indicated the value of superphosphate or rock phosphate to this soil. Farmers are urged to test the relative effects of these fertilizers on their own soils under their particular conditions. Larger crop yields may be secured on the Carrington silt loam thru the proper use of farm manure, lime and superphosphate, or rock phosphate.

## CLYDE SILTY CLAY LOAM (85)

The Clyde silty clay loam is the third largest drift soil in the county, covering 3.0 percent of the total area. It occurs in numerous small areas within the Carrington silt loam and Carrington loam uplands of the county. It is found developed only in the western part of the county in association with these drift types, occupying small flats or depressions extending in finger-like areas up the gentle slopes of the Carrington soils. There are no large individual areas of the type, but it is found most extensively developed in the extreme south-western townships.

The surface soil of the Clyde silty clay loam is a black heavy plastic silty clay loam or clay loam to a depth of 6 inches. Below this point the soil is a dark brown to black clay or clay loam extending to a depth of 20 inches. From 20 to 36 inches the subsoil is an olive gray or grayish-brown plastic silty clay or clay mottled with brown, yellowish-brown and gray and occasionally with rusty brown iron stains. In some places the surface soil contains fine particles of quartz, and in some areas the surface soil adjacent to the Carrington loam is so modified that it appears to be a heavy coarse loam to a depth of 2 to 3 inches. Locally a yellowish-brown sandy loam is often encountered below 30 inches. Small patches which have a surface layer of muck 2 to 6 inches in thickness are found thru the areas of Clyde silty clay loam. These are too small, however, to indicate on the map.

The type is flat to depressed in topography, and the drainage is naturally very poor. Artificial drainage is necessary for good crop production on this soil.

Only a small portion of the Clyde silty clay loam is under cultivation. Coarse water grasses grow on the unreclaimed portions and this is cut and furnishes a coarse hay. On the well drained cultivated areas corn is successfully grown and yields 35 to 65 bushels per acre. The hay crops produce 1½ to 3 tons per acre. Small grain crops are grown but are apt to lodge, especially in wet seasons.

The first need of this soil, to make it most satisfactorily productive, is adequate drainage. When drained, proper cultivation is necessary. It is important that the soil should not be worked when too wet, as it is apt to clod and bake. The type is acid in reaction, and applications of lime are necessary for the best growth of legumes. The use of a phosphate fertilizer on the type would be of value, and tests with superphosphate are recommended. Crop yields on this soil may be materially increased thru the proper application of farm manure, lime and superphosphate, provided adequate drainage has previously been brought about.

## LINDLEY LOAM (65)

The Lindley loam is a minor type, together with the shallow phase which is much more limited in extent, covering only 1.0 percent of the total area. It occurs in numerous areas in the southwestern part of the county, in association with the Carrington soils on the drift uplands. The largest areas of the type are found in Sumner Township, north and west of Spillville and directly south of Spillville. Other areas of considerable size occur in the southwest corner of the county in Jackson Township and in the vicinity of Ft. Atkinson. A few small areas are found in the northwestern part of the county. Small areas of

from 10 to 50 acres in size are scattered on the slopes along Turkey River and along some of the other creeks and tributaries in other parts of the county.

The surface soil of the Lindley loam is a light brown to brown gritty loam, containing considerable very fine sand and extending to a depth of 10 inches where it passes into a reddish-brown or yellowish-brown gritty silty clay loam subsoil. Considerable medium and coarse sand, and some gravel, are found in the subsoil. In Section 14 of Bluffton Township the soil is more sandy than typical and some rock outcrops occur along the river.

The Lindley loam is gently to steeply rolling in topography. Drainage is good on the gentle slopes and excessive on the steeper areas. The land was originally forested and about 35 percent of the type is now under cultivation, the remainder being covered with a thin timber growth and used for pasture purposes.

The yields of general farm crops on the cultivated areas of the type are about the same as those secured on the Carrington loam. Considerable increases in crop yields may be secured from the same treatments recommended for the Carrington loam. The liberal application of farm manure is very desirable on this type and larger crop yields will follow its use. If farm manure is not available for application, the turning under of leguminous crops for green manures is very desirable. The type is acid in reaction and applications of lime are necessary for the best growth of leguminous crops such as clover and alfalfa. The use of a phosphate fertilizer would undoubtedly be of value on this type and tests of superphosphate are strongly recommended.

#### LINDLEY LOAM (SHALLOW PHASE) (207)

The shallow phase of the Lindley loam is minor in extent, covering only 576 acres and less than one-tenth of one percent of the total area of the county. It occurs only in one area in the southwest corner along the Chickasaw County line in Sections 19 and 30 of Jackson Township, 2½ miles west of Jackson Junction.

The surface soil of the shallow phase Lindley loam is a yellowish-brown friable silt loam extending to a depth of 12 inches and containing considerable silt. When dry, the surface soil has a light grayish or light yellowish appearance. Below 12 inches the subsoil is a tenacious yellowish-brown clay loam, containing much sand and small pieces of rock. At a depth of 30 inches limestone rock is usually encountered and coarse gravel pockets are sometimes found. There is some variation in the character of the surface soil, fine sand and coarse sand being irregularly scattered thru the surface layer. In some areas pockets 20 to 30 feet wide have the texture of a coarse sandy loam. The phase varies from the typical Lindley loam in the shallower depth to the bedrock and in the heavier character of the lower subsoil. In topography the type is similar to that of the Carrington loam. Natural drainage is fair.

The shallow phase of the Lindley loam is all in cultivation and general farm crops are grown. Yields are much the same as those secured on the Carrington loam, except in dry seasons when the land tends to be drouthy. The type will respond profitably to applications of farm manure and also to the use of leguminous crops as green manures. Both of these treatments tend to reduce the danger of crop injury during periods of drouth. The type is acid in reaction and addi-

tions of lime are necessary if legume crops are to be grown. The application of superphosphate will bring about profitable crop increases, and tests of this phosphate are strongly recommended.

#### CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor type, covering only 0.8 percent of the total area. It is found in a number of small areas, ranging in size from 10 to 300 acres, which are scattered over the Iowan drift portion of the county in the western townships. The largest areas of the type are found in Sumner Township, northwest of Spillville. Other areas of the type are found in Jackson, Washington, Lincoln and Orleans Townships.

The surface soil of the Carrington fine sandy loam is a dark grayish-brown to dark brown friable fine sandy loam extending to a depth of 14 inches. The subsoil is a brown to dark brown fine sandy loam to a depth of 30 inches, being just slightly lighter in color than the surface soil. Below this point there is a yellowish-brown gritty silty clay loam. Variations occur in the different areas in the texture of the surface soil. In Section 26 of Fremont Township, the texture ranges from a loam to a fine sandy loam, being spotted and containing more silt and coarse sand than the typical soil. Another area in Section 34 of Lincoln Township is heavier in texture both in the soil and subsoil and lighter in color than the typical soil.

The Carrington fine sandy loam is found on the ridges or gentle hill slopes. The topography is gently undulating to rolling. Drainage is good to excessive.

Practically all the type is under cultivation and general farm crops are grown. The yields are usually somewhat lower than those secured on the Carrington loam, altho in seasons of abundant rainfall yields are much the same as those obtained on the heavier textured soil. Increases in the yields of general farm crops on this type may be brought about thru proper methods of management and treatment. The use of farm manure is very desirable on the soil, and liberal applications of this material should be made. Where farm manure is not available leguminous crops should be turned under as green manures. The soil is acid in reaction, and applications of lime are necessary for the best growth of leguminous crops. Phosphate fertilizers would undoubtedly prove profitable, and the application of superphosphate is recommended on this soil.

#### DICKINSON SANDY LOAM (199)

The Dickinson sandy loam is a minor type, covering 0.7 percent of the total area. It is found in a number of areas in the southwestern townships, being most extensively developed in Sumner Township, the largest area being found west and northwest of Spillville. Other areas are found in Jackson, Washington, and Calmar Townships. Three small areas are found on the southern Madison Township line.

The surface soil of the Dickinson sandy loam is a dark grayish-brown coarse sandy loam containing some gravel. At a depth of 8 to 10 inches this passes into a yellowish-brown coarse loam, containing fine sand in considerable amounts. Below 18 to 24 inches coarse sandy gravel is found, the gravel ranging from medium to coarse; occasionally some boulders are present. Along the Chickasaw County line in the southwest corner of the county, in Sumner and Jackson Town-

ships, there is a variation from the typical soil. Here the subsoil from 12 to 30 inches is a yellowish-brown, coarse gravelly silty clay loam underlaid by yellowish-brown coarse gravelly sand. The surface soil here also has a higher proportion of silt than the typical soil and varies in texture from a loam to a sandy loam.

In topography the Dickinson sandy loam is undulating to rolling. The drainage is good to excessive. In some places on the steeper slopes erosion has been active and much of the surface soil has been removed, leaving only 3 or 4 inches of soil. In some cases the entire surface soil has been washed away.

Practically all of the type is cultivated, and general field crops are grown. Crop yields are good in favorable seasons and compare favorably with those secured on the Carrington fine sandy loam. In dry seasons crops are apt to be injured and yields considerably reduced. The chief needs of this soil to make it more productive are the addition of farm manure or the plowing under of leguminous crops for green manure purposes. Both treatments will increase the water-holding power of the soil and reduce the danger of crop injury in dry seasons. Liberal applications of farm manure should be made whenever possible. When farm manure is not available for use, then the turning under of leguminous crops for green manures will prove equally valuable. The type is acid in reaction and should be limed for the best growth of leguminous crops. The use of a phosphate fertilizer would undoubtedly prove of value on this type, and tests of superphosphate are strongly recommended.

### LOESS SOILS

There are five loess soils in the county classified in the Tama, Fayette, Dodgeville and Clinton series. Together they cover almost two-thirds of the county, 61.2 percent of the total area.

#### TAMA SILT LOAM (120)

The Tama silt loam is the largest loess soil and the most extensively developed type. It covers 30.9 percent of the total area and is found extensively developed in the northern and entire eastern and central portions. Large areas of the type occur on the tops of divides and on the gentle slopes over the entire loessial area. Thruout the entire eastern part of the county it is in close association with the Fayette silt loam on the uplands. In Orleans and Madison Townships and in the southwest corner of Bluffton Township, the loess covering is thin and in many places the Carrington soils are developed on the points of ridges and on hillsides. Boulders of drift origin are found on the slopes, sometimes at considerable distances from the edge of the drift areas. Near the boundaries between the drift and loess regions there are prominent areas of residual soils on the ridges, and flat upland residual benches adjacent to small streams. In many areas, where the Tama silt loam adjoins the Fayette silt loam, the boundary lines are rather arbitrarily established, as there is a gradual change in color from the darker to the lighter soil.

The surface soil of the Tama silt loam is a dark brown friable smooth silt loam extending to a depth of 12 to 18 inches. At this point it grades into a dark brown to brown silty clay loam, changing abruptly at 20 to 22 inches into a compact friable yellowish-brown silty clay loam to clay loam. In the different

areas the depth of the surface soil is quite variable. The more level or gently undulating areas are darker colored to a depth of 14 to 18 inches. On the hill slopes the surface soil varies from 4 to 10 inches in depth with many exposures of a light yellowish-brown subsoil in patches. Locally, in the flatter areas, there are faint gray mottlings and occasional iron stains in the lower subsoil below 30 inches.

In topography the Tama silt loam is almost flat to rolling. Along the east side of Hesper Township and in Hyland Township there are a number of flat areas from 1 to 5 square miles in extent, along the outer edge of which a definite wall 30 to 100 feet high extends in semicircular fashion. The flat Tama soil appears as the bottom of a huge bowl. This flat is rather poorly drained, only one stream cutting thru it at the center. Thruout the remainder of the county the topography of the Tama is gently undulating on the wider interstream areas to rolling along the drainage channels. Where erosion has occurred along the steeper slopes, much of the surface soil has been washed away, exposing the lower subsoil or underlying limestone. The drainage of the type is generally good, except in the few flat areas already mentioned.

Practically all of the Tama silt loam is in cultivation. Only a small part is used for pasture, and general farm crops are commonly grown. Nearly one-half of the type is used for corn, and yields range from 30 to 60 bushels per acre. In some areas yields of 75 to 80 bushels are often secured. Oats yield from 30 to 65 bushels per acre, averaging from 35 to 40 bushels. Timothy and clover yield about 1½ tons per acre. Some timothy is grown for seed. Small acreages are used for winter and spring wheat. Alfalfa is grown on small areas with satisfactory yields. Some barley is grown in the rotation in place of oats. Potatoes and small fruits are raised on limited areas and produce very satisfactorily.

The Tama silt loam is naturally a productive soil and yields of general farm crops are ordinarily good. Increases in crop yields may be secured, however, thru proper methods of treatment. The application of farm manure will bring about considerable increases in crop yields, as will also the turning under of leguminous crops as green manures. The type is acid in reaction, and the use of lime is of distinct value, especially when legumes such as alfalfa and clover are to be grown. The use of a phosphate fertilizer is recommended on this type, and superphosphate or rock phosphate should be applied in order to secure maximum crop yields. Tests of the two phosphates on individual farms are strongly recommended. The experiments referred to earlier in this report indicate the beneficial effects of phosphate fertilizers on this particular soil, and the addition of a phosphate fertilizer should prove profitable under individual farm conditions.

#### FAYETTE SILT LOAM (163)

The Fayette silt loam is the second largest loess soil and the second most extensively developed type. It covers 25.6 percent of the total area. It is developed in large areas thruout the northern, eastern, and central portions being closely associated with the Tama silt loam on the loessial uplands. It is found on the slopes and bluffs all along the Upper Iowa River and extending back along its tributaries. Large areas are developed along Canoe Creek. Smaller areas are found on the steeper slopes and ridges in the hilly areas along the deeper

valleys of the loessial portion of the county. It normally occurs on the slopes and narrow ridge tops in the steeply rolling, hilly or broken country and separates the more gently undulating areas of upland Tama silt loam from the streams.

The surface soil of the Fayette silt loam is a grayish-brown or yellowish-brown smooth silt loam extending to a depth of 8 inches. Below this point the texture is somewhat heavier and the color is somewhat lighter to a depth of 20 inches. The subsoil at that point becomes a yellowish-brown friable silty clay loam to clay loam, crumbly and friable when dry. In Hesper and Highland Townships there are areas in which the surface soil has a more ashy or grayish color than the typical development, being a whitish-gray when dry and resembling the surface soil of the Marion soils of southeastern Iowa. In these areas the subsoil has a faint grayish-brown mottling below 20 inches. Here the soils are developed in flat depressed sink-like areas which are 10 to 30 feet across and 6 to 16 feet in depth. There is no natural run-off or natural drainage to these areas. They are particularly well developed in Sections 21 and 28 of Hesper Township. The lower slopes of the forested areas and the more gentle ridge tops have a brown to almost dark brown surface layer 3 to 4 inches in depth. On the steeper slopes, where erosion has occurred more extensively, are patches of a yellowish-brown clay loam to silty clay, the texture becoming heavier where more extensive erosion has occurred. Variations of the surface soil in depth and color are found thruout areas of this type.

In topography the Fayette silt loam varies from rough to rolling or hilly thruout the general typical development to the flat areas which have been described that vary considerably in characteristics from the typical soil. Drainage is adequate and may even become excessive on the steep slopes. Erosion has occurred to a considerable extent on the steeper areas of the type and much of the surface soil has frequently been carried away. Valleys of the streams are deeply V-shaped with long steep slopes. Limestone outcrops are commonly found at the tops of the slopes or at the base, forming sharply defined bluffs.

About 75 percent of the type is in cultivation, the remainder being forested and used for pasture purposes. Corn is the chief crop grown on the cultivated areas and averages 30 to 50 bushels per acre. Oats yield from 30 to 45 bushels and clover and timothy 1 to 2½ tons per acre. Some barley is grown, with yields of 20 to 25 bushels per acre. A few small orchards and some tree and bush fruits all yield very satisfactorily.

The needs of the Fayette silt loam include, first of all, the liberal incorporation of organic matter. Applications of barnyard manure in large amounts can be profitably employed on this soil. When farm manure is not available, the growing of leguminous crops for green manure purposes is very desirable. The type is acid in reaction, and additions of lime are necessary for the best growth of legume crops. The use of a phosphate fertilizer would undoubtedly prove of value, and superphosphate should be tested on this soil. Applications to small areas will indicate whether or not the fertilizer will prove profitable, and, if it is, additions may then be made to more extensive areas. Experimental work carried out on this soil has indicated that the application of phosphate in the form of superphosphate and, in general, the treatment of the type with a phos-

phate fertilizer, should prove of considerable value. The rougher areas of the type should undoubtedly be kept in pasture in order to prevent the extensive erosion which will occur on these areas if they are cultivated.

#### DODGEVILLE SILT LOAM (204)

The Dodgeville silt loam is the third largest loess soil covering 3.7 percent of the total area. It is developed in a number of areas in the western townships, particularly on the steeper areas adjacent to Turkey River. The largest development of the type is found along this river in the vicinity of Ft. Atkinson and Spillville. Other areas occur adjacent to some of the other streams in the county. One area of considerable size is found in Madison Township, adjacent to Walnut Creek. The type is most extensively developed in Calmar and Madison Townships.

The surface soil of the Dodgeville silt loam is a very dark brown to black silty clay loam extending to a depth of 8 inches. Below this point there is a layer of dark brown to black light silty clay loam from 12 to 14 inches in thickness resting on limestone. Where the limestone occurs at a depth of nearly 3 feet there is usually an inch or two of buff or light yellowish-brown silty clay or clay, often with a bluish-green or drab mottling. Small limestone fragments are found scattered thru the soil horizon. In places there is a small amount of coarse sand in the surface layer extending to a depth of 10 to 12 inches. On some of the ridge tops and slopes the soil is shallow and contains more and larger fragments of limestone. In some places on the crests and in spots on the slopes the soil consists of a light yellow or buff-colored silt loam only 4 to 6 inches in depth. These areas are undoubtedly derived from sandstone and are identical with the Dubuque silt loam but are too small to separate on the map. In many of the areas there is considerable loess mixed with the soil and it is so closely allied to the loess type in other counties that it has been included with the loess group in this county. Much of the surface soil over large areas of the type is composed entirely of loessial material. In the area in Section 20 of Decorah Township practically all of the surface soil is composed of loessial material. A soil somewhat heavier in texture than the typical is found in Section 7 and 8 of Calmar Township, in three small areas in Section 22 and 23 of Madison Township and in an area a mile north of Ft. Atkinson.

In topography the Dodgeville silt loam is gently undulating to gently sloping, drainage is usually adequate but may be somewhat deficient in some areas. In other cases the run-off is good, and even excessive and leading to some erosion in certain instances.

Practically all of the type is under cultivation and general farm crops are grown. Corn yields 25 to 50 bushels per acre, oats from 20 to 45 bushels per acre and clover and timothy 1 to 1½ tons per acre.

Farm manure should be applied in liberal amounts to this soil and the application of a phosphate fertilizer is necessary. Altho the soil is largely derived from limestone and rests upon lime rock, the surface is apt to be acid in reaction. In such cases the use of lime is necessary for the best growth of legumes. Tests of superphosphate on the type are strongly recommended.

## CLINTON SILT LOAM (80)

The Clinton silt loam is a minor type, covering only 0.8 percent of the total area. It is developed in one large area in the southeastern part of the county in Bloomfield Township, extending over the township line into Frankville Township and to the Allamakee County line on the east. It covers an area of 3,584 acres.

The surface soil of the Clinton silt loam is a grayish-brown or yellowish-brown smooth silt loam to a depth of 10 inches. Below this point the subsoil is a grayish-brown heavy silt loam to silty clay loam, changing at 20 inches into a yellowish-brown tenacious clay loam or clay. Faint gray mottlings and iron stains occur at various depths around 36 inches.

In topography the Clinton silt loam is much the same as the Fayette, varying from rolling to hilly and being broken and cut by short gullies. The land was originally forested with oak, hickory, basswood, elm and ash, but most of the timber has been removed and the type is largely under cultivation. The steeper eroded areas are used for pasture. General farm crops are grown on the cultivated areas, and the yields are very much the same as those secured on the Fayette silt loam.

This type needs liberal applications of organic matter. The turning under of leguminous crops as green manure would be of large value. Applications of farm manure have been found to bring about large increases in the yields of general farm crops. The type is acid in reaction, and applications of lime are necessary for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly be of value on this soil, and tests of superphosphate are strongly recommended. Experimental work on this soil indicates that phosphorus fertilizers will bring about distinctly profitable increases in crop yields.

## FAYETTE FINE SAND (208)

The Fayette fine sand is a minor type, covering only 0.2 percent of the total area. It is found in small areas on the east slopes southwest and northeast of Freeport, occurring on a rather steep slope below a ledge of broken limestone outcrop. Another area of the type occurs in Section 30 of Canoe Township.

The surface soil of the Fayette fine sand is yellowish-brown fine sand passing at 15 inches into a slightly lighter yellowish-brown fine sand. In many places it contains small pebbles and bits of quartz rock. Both soil and subsoil are quite uniform in color and texture. Drainage of the type is fair to excessive.

Most of the soil is uncultivated or in grasses which are used entirely for pasture purposes. A few melons are grown on the lower slopes south of Freeport. The type is of little importance agriculturally.

When cultivated, this soil is particularly in need of organic matter, and liberal applications of farm manure should be made or leguminous crops should be turned under for green manuring purposes. Increasing the organic matter supply of the soil will make the type more productive, more retentive of moisture and reduce any danger of crop injury during dry seasons. The use of fertilizing materials would be of value on this soil for the growth of general farm crops and particularly for the growing of truck crops. Phosphorus fertilizers, especial-

ly superphosphate, should be used for general farm crops. Some complete fertilizer would undoubtedly be of value where truck crops are grown.

### TERRACE SOILS

There are 12 terrace types classified in the Millsdale, O'Neill, Waukesha, Buckner, Jackson, Judson, Plainfield and Bremer series. They are all small in area, however, and together they cover only 3.1 percent of the total area.

#### MILLSDALE SILT LOAM (209)

The Millsdale silt loam is the most extensively developed terrace soil, covering 0.5 percent of the total area. It occurs chiefly in the south central part. Nearly all of the type is found south and southeast of Ft. Atkinson along Turkey River, extending up Brockamp Creek to Festina, which is partly located on this soil. It occurs on flat terrace benches 20 to 30 feet above the stream.

The surface soil of the Millsdale silt loam is a dark brown to almost black heavy silt loam, extending to a depth of 15 inches. The upper subsoil is a brown to dark brown heavy silt loam containing small particles of quartz or limestone. When dry the subsoil near the parent limestone is a reddish or chocolate brown in color. The soil lies on a limestone bench, which occurs at a depth of 24 to 30 inches. In places there is a layer of 3 to 4 inches of decayed limestone directly on the limestone bed and underlying the soil layer. In some places there is a variation in texture, the range being from a light silt loam to a light silty clay loam. The heavier textured areas usually occur in small pockets or strips that are slightly depressed and too small to show separately on the map. In some areas there is considerable sand mixed with the surface soil. Small areas of the Millsdale loam too small to separate on the map are included with the type.

Practically all of the soil is under cultivation and general farm crops are grown. In a few places the underlying limestone occurs at 4 to 6 inches from the surface and these spots are inclined to be drouthy. With the exception of these shallow areas, crop production on the soil is usually satisfactory. The type will respond, however, to liberal applications of farm manure and to the use of leguminous crops as green manures. Applications of lime are of value in bringing about the best legume yields. Tests of superphosphate are recommended.

#### O'NEILL LOAM (108)

The O'Neill loam is the second largest terrace soil, covering 0.5 percent of the total area. It is found most extensively developed in the western part of the county, along Turkey River and the larger tributaries. Other areas are found along Little Turkey River and its tributaries, in the extreme southwestern corner of the county. A few narrow strips of the type occur along the Upper Iowa River between Freeport and the lower dam. The surface soil of the O'Neill loam is a brown to dark brown mellow loam extending to a depth of 8 inches. The subsoil from 8 to 20 inches is a yellowish-brown to light brown sandy loam. Below 28 inches there is a yellowish-brown sandy loam to sandy gravel. Large gravel and small boulders are frequently found in the lower subsoil and occasionally scattered thru the soil section.

Practically all of the soil is cultivated and corn, oats and hay are the leading crops grown. Corn yields from 25 to 50 bushels per acre, depending upon

seasonal conditions. Oats yield from 20 to 40 bushels per acre. In some areas melons and truck crops are grown and very satisfactory yields of these crops are secured.

The type is well above overflow and drainage is good to excessive. In dry seasons crops may be injured by drouth. The type is particularly in need of organic matter to make it more productive and less subject to crop injury in dry years. Liberal applications of farm manure would be of value and the frequent plowing under of green manure crops would add considerably to the fertility of the soil. Both soil and subsoil are acid and additions of lime are necessary especially if leguminous crops are to be grown. The use of a phosphate fertilizer would undoubtedly prove of value for general farm crops, and applications of superphosphate are recommended. Where truck crops are to be grown, the use of a complete commercial fertilizer would undoubtedly prove profitable.

#### WAUKESHA SILT LOAM (75)

The Waukesha silt loam is a minor type, covering only 0.4 percent of the total area. It is found in a number of small areas in various parts of the county, along Turkey River and some of its tributaries, along the tributaries of Walnut Creek, along the Upper Iowa River at Kendallville and Plymouth Rock and along tributaries of the Upper Iowa River north of Plymouth Rock. The largest area of the type is found about a mile east of Ossian. The town of Decorah is partly built on a considerable area of the soil. Another area which is rather important is found in Section 5 of Madison Township.

The surface soil of the Waukesha silt loam is a dark grayish-brown to black mellow friable silt loam, grading at 18 inches into a light brown silty clay loam to clay loam, rather uniform in color. At about 24 inches the subsoil changes to a yellowish-brown to light yellowish-brown clay loam. The lower subsoil below 30 inches contains yellowish-brown or gray mottlings and some iron stains.

The type occurs on benches 6 to 16 feet above the streams. On the terrace, a mile and a quarter northeast of Plymouth Rock, the surface soil ranges from a silt loam to almost a loam. In Section 1 of Sumner Township there is a small area with a gray mottled subsoil resembling the Bremer. The subsoil of the terraces around Decorah is slightly heavier than typical and faintly mottled with gray. Here the soil horizon is from 3½ to 6 feet or more in thickness, increasing in depth towards the bluffs.

In topography the soil is level to flat, the typical terrace or bench-like topography. Drainage is generally adequate. In a few of the areas where the subsoil is heavy, artificial drainage would be of value.

Practically all of the soil is under cultivation and yields of general farm crops are much the same as those on the Tama silt loam. The needs of the soil for better crop production are similar to those discussed for the Tama silt loam. The type will respond to applications of farm manure and the turning under of leguminous crops as green manures. The use of lime is very desirable for the best growth of legumes. The application of a phosphate fertilizer would undoubtedly prove profitable and tests of superphosphate and rock phosphate are recommended.

## BUCKNER LOAM (38)

The Buckner loam is a minor type, covering 0.4 percent of the total area. It is found along all the streams of any size in the drift region and along the Upper Iowa River. Numerous small areas of the type are developed in various parts of the county. There are no large individual areas of the type; the largest development is found in Washington Township along the Turkey River.

The surface soil of the Buckner loam is a dark brown friable loam extending to a depth of 15 inches. The subsoil is a brown to light brown sandy loam to loamy sand. There are some variations in the surface soil and it ranges from a heavy loam to almost a sandy loam. The subsoil is quite uniform, altho in some cases there are small pockets of coarse sand and gravel. The areas in Sections 9 and 16 of Glenwood Township are lighter in color than the typical, being a lighter brown in both soil and subsoil. These areas are somewhat higher than the typical soil, being located from 15 to 20 feet above the stream channel. They contain a higher percentage of silt, being almost a silt loam towards the edge of the bench. Small areas in Sections 15, 27 and 34 of Washington Township and in Sections 30 and 32 of Calmar Township, along Turkey River, contain a large proportion of fine sand and approach a fine sandy loam in texture.

Practically all of the Buckner loam is in cultivation. Drainage is good. Yields of general farm crops are very similar to those secured on the Carrington loam except in dry seasons or periods of drouth. Where the rainfall is deficient crops are apt to suffer.

The needs of this soil for better crop yields are primarily for the addition of organic matter. Liberal applications of farm manure should be made, and the turning under of leguminous crops for green manure purposes would be of large value. The type is acid in reaction, and additions of lime are necessary for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly prove of value, and superphosphate should be applied to small areas to determine whether or not profitable returns from its use may be secured.

## O'NEILL SANDY LOAM (126)

The O'Neill sandy loam is a minor type, covering only 0.4 percent of the total area. It is found in a number of small scattered areas, mainly along Turkey River and its tributaries. Two very small areas occur along Little Turkey River, and a few small bodies lie along the Upper Iowa River. There are no large individual areas of the type.

The surface soil of the O'Neill sandy loam is a dark brown loose sandy loam to a depth of 8 inches. It contains, also, considerable coarse sand and some gravel. The upper subsoil is a light brown to brown coarse sandy loam or gravelly loam. Considerable amounts of coarse gravel and rock are found in the lower soil layers. The subsoil below 20 inches is a mixture of sand and gravel.

In topography the O'Neill sandy loam is level to flat. Drainage is thoro and the soil is drouthy in dry seasons. General farm crops are grown and yields are very much the same as those secured on the O'Neill loam except in dry seasons when crops suffer more than they do on the loam. The needs of this soil are the same as those discussed for the O'Neill loam. The incorporation of organic matter is most important and the application of farm manure is very desirable. The turning under of leguminous crops for green manure purposes would also

prove of large value. The type is acid and additions of lime are necessary for the best growth of legumes. The use of a phosphate fertilizer would be of large value on this soil and tests of superphosphate are strongly to be recommended.

#### BUCKNER SANDY LOAM (40)

The Buckner sandy loam is a minor type covering 0.3 percent of the total area. It is developed only on the terraces of the Upper Iowa and Turkey Rivers and along tributaries of the latter. There are no large areas of the type, but a number of small areas are mapped.

The surface soil of the Buckner sandy loam is a brown sandy loam containing much coarse sand and some gravel. Below 8 inches the subsoil is a yellowish-brown sandy loam, extending to a depth of 28 inches. Here the lower subsoil is a lighter yellowish-brown loamy sand to sand containing some gravel.

In topography this soil is level to flat, drainage is good to excessive. In dry weather crops are injured by drouth. The type is all under cultivation. Corn yields from 25 to 45 bushels per acre and oats 25 to 40 bushels in good seasons. Timothy and clover give fair yields. The soil is adapted to truck crop growing, and good yields of various truck crops might be secured. The type is particularly in need of organic matter, and the liberal application of farm manure is strongly recommended. The turning under of leguminous crops for green manuring purposes would be very desirable on the type. The incorporation of organic matter would reduce the danger of injury to crops in periods of drouth. The type is acid in reaction and additions of lime are necessary for the best growth of legumes. The use of a phosphate fertilizer would be of value and applications of superphosphate would undoubtedly bring about considerable increases in the yields of general farm crops. Where truck crops are grown the use of a brand of a complete commercial fertilizer especially designed for the crop would be of value on this sandy type.

#### MILLSDALE LOAM (188)

The Millsdale loam is a minor type, covering only 0.1 percent of the total area. It occurs generally on the west terraces of the Turkey River, two and three miles south of Ft. Atkinson. There is also a fair sized area southeast of Festina. In Section 18 of Orleans Township at the Howard County line and along the small tributary of the Upper Iowa River there is a small area that slopes toward the stream and merges gradually with the bottomland. Another small area is found in Section 7 of Glenwood Township.

The surface soil of the Millsdale loam is a dark brown to black loose loam to a depth of 10 inches. At 10 to 12 inches the subsoil is a reddish-brown sandy loam or fine sandy loam, containing considerable coarse sand. Beneath this subsoil material is a layer of limestone which occurs at depths from 24 to 34 inches and averages around 30 inches.

In topography the Millsdale loam is generally level to flat, the area in Orleans Township on the Howard County line being the only exception. All of the type is under cultivation, and general farm crops are grown. The yields secured normally compare well with those obtained on the Carrington loam on the upland. Only in the areas where the limestone occurs within 12 to 15 inches of the surface soil is there any danger of drouth injury to crops in dry seasons.

The type will respond to applications of farm manure, and liberal amounts of this material should be employed. It is acid in reaction, and lime should be used for the best growth of legumes. The application of a phosphate fertilizer would undoubtedly be of value on this soil.

#### JACKSON SILT LOAM (81)

The Jackson silt loam is a minor type, covering only 0.1 percent of the total area. It occurs mainly along the Upper Iowa River, beginning one mile east of Bluffton and extending down the river until it leaves the county. A few small areas occur along Canoe Creek and one along the small tributary of the Upper Iowa River in Section 21 of Glenwood Township. The largest area of the type is found two and one-half miles north of Freeport on a high terrace 30 feet above the river channel. Other areas occur in Section 12 of Decorah Township and in Section 36 of Pleasant Township.

The surface soil of the Jackson silt loam is a grayish-brown to grayish-yellowish-brown smooth silt loam, extending to a depth of 8 inches. At this point the soil is a yellowish-brown to buff silty clay loam, passing at 15 inches into a lighter colored but more compact yellowish-brown clay loam. The lower subsoil is friable and similar to the subsoil of the Fayette silt loam. In some areas there are spots or pockets of mixed sandy materials, usually occurring close to the beds of the stream or in overflow land. Occasionally thin layers, 2 to 5 inches in depth, of a fine sandy material occur in strips or patches at the edges of the terrace adjacent to the uplands.

In topography the Jackson silt loam is flat with a gentle slope toward the stream. Drainage is fair. The type is all under cultivation, and general farm crops are grown. The yields of corn normally amount to 25 to 45 bushels per acre, and oats yield 20 to 40 bushels per acre. Clover and timothy yield 1 to 1½ tons per acre.

This soil will respond in a very profitable way to applications of farm manure. Liberal additions of this material are recommended. The turning under of leguminous crops as green manures would also be of value on this soil. The type is acid, and applications of lime would be of value for the growing of legumes. The use of a phosphate fertilizer would undoubtedly prove profitable, and tests with superphosphate are strongly recommended.

#### O'NEILL FINE SANDY LOAM (110)

The O'Neill fine sandy loam is a minor type, covering 0.1 percent of the total area. It occurs in small isolated areas mainly along the Turkey River and its tributaries thruout the drift sections of the county. The largest development of the type is just northwest of Spillville.

The surface soil of the O'Neill fine sandy loam is a dark brown to dark grayish-brown fine sandy loam extending to a depth of 10 inches. At this point the soil becomes a yellowish-brown fine sandy loam to sandy loam changing at 20 inches into a yellowish-brown coarse gravelly sand. The surface soil varies somewhat in texture, ranging from a very fine sandy loam to the typical fine sandy loam in texture. In some areas the gravelly subsoil material occurs in pockets and may appear within 10 to 12 inches of the surface.

All of the O'Neill fine sandy loam is under cultivation, being utilized for

general farm crops or pasture purposes. The type is particularly in need of additions of organic matter to make it more productive, and liberal applications of farm manure are recommended. The turning under of leguminous crops as green manures would also be of value. Both of these treatments would reduce the danger of injury to crops in dry seasons. The type is acid and applications of lime are necessary for the best growth of legumes. The addition of a phosphate fertilizer would undoubtedly be of value and tests of superphosphate are recommended.

#### JUDSON SILT LOAM (131)

The Judson silt loam is a minor type, covering 0.1 percent of the total area. It occurs in a number of areas, the largest development being found along Trout Run. Other isolated areas are found widely scattered along the Turkey River and the Upper Iowa River and a few of their tributaries.

The surface soil of the Judson silt loam is a dark brown to black friable silt loam extending to a depth of 20 inches. The subsoil below 20 inches is a dark brown to black friable heavy silt loam to a light silty clay loam, being just a trifle lighter in color than the surface soil. There is considerable variation in the type, both in the soil and subsoil. There are many small pockets and ridges containing considerable amounts of very fine sand in the surface and subsurface layer and approaching a loam in texture. Along the Upper Iowa River near Decorah, the subsoil is lighter in color than the surface soil, being a loam to very fine sandy loam.

In topography the Judson silt loam is flat, occurring on terraces from 4 to 8 feet above the stream. The natural drainage of the soil is good.

The type is all under cultivation and general farm crops are grown. The yields are very similar to those secured on the Tama silt loam on the uplands. The type will respond to the same treatments recommended for the Tama silt loam. Liberal applications of farm manure will prove of value and the use of leguminous crops as green manures will increase the fertility of the soil. The type is acid, and lime should be applied for the best growth of legumes. A phosphate fertilizer would undoubtedly prove profitable when applied to this soil, and tests of superphosphate and rock phosphate are recommended.

#### PLAINFIELD FINE SANDY LOAM (97)

The Plainfield fine sandy loam is a minor type, covering 0.1 percent of the total area. It is found in a number of areas somewhat limited in size. The largest area, consisting of about 80 acres, is found just north of Spillville. A few small bodies occur along the Upper Iowa River, the largest being one-half mile north of Freeport. Other small areas occur in Sections 7 and 8 of Glenwood Township and in Section 36 of Pleasant Township.

The surface soil of the Plainfield fine sandy loam is a light brown to brown fine sandy loam extending to a depth of 24 inches. The subsoil is a yellowish-brown fine sand. There are many variations from the typical soil. In the area north of Spillville the surface texture is almost a loam. In the area north of Freeport the surface texture varies from a fine sandy loam to fine sand, and the surface is somewhat ridgy. In the southern part of this same area is located a coarse gravelly clay loam which is encountered at a depth of about 3½ feet.

Included with the type is an area adjoining the Fayette County line in Section 32 of Jackson Township, which is adjacent to an area of Plainfield loam mapped in Fayette County. Here the soil is grayish-brown friable fine sandy loam about 8 inches in depth, grading into a yellowish-brown or light brown fine sandy loam underlaid at 26 inches by a bed of sand.

Practically all of the type is in cultivation, and general farm crops are grown. Yields are variable, depending largely upon rainfall and seasonal conditions. The soil is drouthy in dry years and crops may suffer in seasons of restricted rainfall.

The chief need of this soil is for organic matter. Liberal applications of farm manure should be made, and leguminous crops turned under as green manures would be of considerable value. The type is acid, and lime should be used for the best growth of legumes. Phosphate fertilizers would undoubtedly prove of value, and tests of superphosphate are strongly recommended.

#### BREMER SILTY CLAY LOAM (43)

The Bremer silty clay loam is a minor type, covering 0.1 percent of the total area. A number of small isolated areas of the type are developed chiefly along Turkey River and its tributaries.

The surface soil of the Bremer silty clay loam is a very dark brown to black silty clay loam, changing to a dark brown to black heavy clay loam at depths of 8 to 15 inches. The lower subsoil, below 24 to 30 inches, is a yellowish-brown tenacious silty clay to clay, mottled with gray. Occasionally, iron stains occur below 30 inches. A small area of Bremer loam in Section 34 of Washington Township is included with this type, but no other areas of the loam were mapped.

The surface soil of the Bremer loam, to a depth of 12 inches, is a dark brown to black silty friable loam. The subsoil is practically identical with that of the typical Bremer silty clay loam. In Sections 2 and 16 of Sumner Township the establishment of the boundary lines between the terrace and the uplands has been made rather arbitrarily, as there is a gradual gradation from the Bremer silty clay loam to the adjacent upland.

The type is level to flat in topography, and the drainage is poor. All of the soil is in cultivation and general farm crops are grown. The chief need of the soil, to make it more productive, is the installation of tile to bring about adequate drainage. The application of a small amount of farm manure would be of value on newly drained areas. The type is acid and lime should be applied to correct the acid condition. The use of a phosphate fertilizer would undoubtedly be of value and tests of rock phosphate and superphosphate are recommended.

### SWAMP AND BOTTOMLAND SOILS

There are 6 swamp and bottomland soils and these with the area of muck make a total of 7 swamp and bottomland soils. They are classified in the Wabash, Cass and Genesee series. Together they cover 8.6 percent of the total area.

#### WABASH SILT LOAM (26)

The Wabash silt loam is the largest individual bottomland soil and the fifth largest type, covering 5.3 percent of the total area. It occurs along all of the larger streams and tributaries thruout the loessial section. There are also a few

scattered areas in the drift region along Turkey River west of Ridgeway. The largest developments of the type are along Upper Iowa River northwest of Decorah.

The surface soil of the Wabash silt loam is a very dark grayish-brown to black friable silt loam, extending to a depth of 14 inches. It contains much fine sand. The subsoil is a grayish-brown or dark grayish-brown clay loam to clay, mottled with gray and sometimes yellowish-brown. Occasionally, there are faint iron stains. Along the Upper Iowa River the soil is characteristically black but is shallow, in places resting on limestone at depths of 6 to 18 inches. In Sections 6 and 7 of Decorah Township, in Section 30 of Canoe Township and in Section 25 of Bluffton Township, small strips of the type are sometimes found in which the subsoil at 34 inches is a black, very fine sand to fine sand. These areas are particularly high in organic matter content. Along some of the shorter tributary streams in the southeast corner of the county, the surface soil is somewhat lighter in color, being formed by a mixture of colluvial wash from the light colored Fayette and Clinton silt loam with that from the darker colored upland types.

Along the smaller streams the strips of this type are narrow and used mainly for pasture. On the uncultivated areas there is a luxuriant growth of blue grass, and a few scattered trees are found. On the cultivated areas corn is the chief crop grown, yielding 25 to 60 bushels per acre. Some clover and timothy is grown with yields of 1 to 2 tons per acre. For successful crop yields, this soil should be protected from overflow and adequately drained. Small amounts of farm manure would be of value on newly drained areas. The type is acid, and lime should be applied for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly prove profitable, and tests of rock phosphate and superphosphate are recommended.

#### CASS LOAM (18)

The Cass loam is the second largest bottomland soil, covering 1 percent of the total area. It is found mainly along the Turkey River and Upper Iowa River, extending in some places back along the tributary streams. There are a number of individual areas of this type.

The surface soil of the Cass loam is a dark brown to almost black loam, extending to a depth of 8 inches. It contains considerable fine sand. The subsoil is a dark brown or brown fine sandy loam, grading at 24 inches into a yellowish-brown or light yellowish-brown fine sand. Along the Turkey River the type is most characteristically developed; the subsoil being a light yellow medium or fine sand. Along the Upper Iowa River there is a high content of silt in the subsoil, and the texture usually varies from a fine sandy loam to a sand or fine sand.

In topography the Cass loam is nearly flat, altho there are occasionally low ridges and mounds which are worked over by flood areas. The streams follow a meandering course thru the bottoms. The drainage is good on the type except in a few low swales and depressions formed from old stream courses. The type is subject to overflow after heavy spring and fall rains. Originally the soil was forested, mainly with willow, ash, cottonwood, walnut and elm, but only a few trees remain.

The type is utilized largely for pasture, and only a very small part is under cultivation. The cultivated areas are fairly productive. Corn is the chief crop, and yields are good. When cultivated, this soil should receive liberal applications of farm manure, or leguminous crops for green manures should be turned under. The soil is acid and should be limed. The use of a phosphate fertilizer, such as superphosphate, would undoubtedly prove of considerable value.

#### WABASH LOAM (49)

The Wabash loam is the third most extensively developed bottomland soil, covering 0.9 percent of the total area. It is found in numerous areas, being chiefly developed along Turkey River and the upper part of Walnut Creek. Areas are found, also, along practically all the streams in the western part of the county. Several small areas occur along the upper course of the Upper Iowa River, beginning one mile east of Bluffton and extending westward to the county line.

The surface soil of the Wabash loam is a black mellow loam, extending to a depth of 12 inches. The subsoil to 24 inches is a brown to dark brown heavy clay loam, containing some coarse sand and small gravel. At 24 inches it changes to a yellowish-brown clay loam to clay with some brown, yellowish-brown, or grayish-brown mottlings and a few iron stains. Small pockets of silty clay or clay and areas of sand and gravel occur over the surface and thru the soil. In the area a mile east of Bluffton the soil varies from 3 to 4 inches to 3 to 4 feet in depth and rests on a bed of limestone. In a few places the limestone outcrops at the surface. Numerous other textural variations of the type occur thruout the various areas.

In topography the Wabash loam is flat, but, except in small areas, the drainage is good. The areas along the larger streams are mostly in cultivation. Somewhat more than half the type is cropped, the remainder being utilized for native blue grass pasture. The trees on the uncultivated areas consist, mainly, of oak, red haw, willow and ash. Corn is the chief crop grown on the cultivated section and yields 25 to 50 bushels per acre, depending largely upon the seasonal conditions. When cultivated, this soil will respond to applications of farm manure, and liberal amounts of this material should be used. It is acid in reaction and should be limed for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate and rock phosphate are recommended.

#### WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is the fourth largest bottomland soil in the county, covering 0.8 percent of the total area. It is found mainly in the bottoms, along Walnut Creek and its tributaries, Dry Run and a branch of Turkey River in the southwest corner of Lincoln Township. There are also small areas in Sections 3, 4 and 23 of Military Township, occurring at the heads of small drainage lines and over the southeastern loessial area, particularly along the head tributaries of Yellow River.

The surface soil of the Wabash silty clay loam is a very dark grayish-brown to black silty clay loam, extending to a depth of 8 to 10 inches. The subsoil is a dark brown to black tenacious silty clay to clay, changing at 20 to 22 inches

into a grayish-brown clay loam to clay mottled with yellowish-brown and gray. Iron stains frequently occur in the lower part of the three foot section. Along some branches of the Upper Iowa River, especially in Madison and Lincoln Townships, there is a variation from the typical soil. Here, along the outer edges adjacent to the upland drift soils, there is much coarse sand and gravel in the surface soil. Occasionally, boulders are found. In some of the poorly drained spots of the type a thin mucky layer 2 to 3 inches in depth is found.

The Wabash silty clay loam occurs in depressed areas, and drainage is poor. Practically all of this type is used for pasture purposes, altho some wild hay is cut. The land is subject to overflow and is not suitable for cultivation until it has been protected from overflow and thoroly drained.

When this treatment is practiced, satisfactory yields of general farm crops might be secured; as the type is naturally highly productive. When drained and protected from overflow, it will respond to small applications of farm manure, which stimulate the production of available plant food. It should be limed to correct the acid conditions prevailing in it, and applications of superphosphate would undoubtedly prove profitable.

#### CASS FINE SANDY LOAM (130)

The Cass fine sandy loam is a minor type, covering 0.4 percent of the total area. It is most extensively developed along Turkey River, occurring in disconnected strips one to three miles in length. It also occurs along Brockamp Creek to Festina and along the westerly branch entering Turkey River at Spillville. There is another development along the tributary of Turkey River four miles northwest of Spillville, in Sections 10 and 11. A small area lies near the Fayette County line on Little Turkey River. There are three small areas along the Upper Iowa River three miles northwest of Bluffton and one area three miles northeast of Freeport in Section 9 of Glenwood Township.

The surface soil of the Cass fine sandy loam is a dark brown fine sandy loam extending to a depth of 8 inches. The subsoil is a yellowish-brown fine sand to loamy fine sand, grading at 24 inches into a lighter yellowish-brown fine sand. The soil and subsoil are quite uniform in color and texture, and there is little coarse material to a depth of 36 inches. Along Little Turkey River and its tributaries are some areas of Cass sandy loam. These have been included with the type because of their small extent.

The Cass fine sandy loam is nearly all used for pasture, only a few small fields being in cultivation. Corn is the chief crop grown on the cultivated areas. For the best growth of cultivated crops this type should receive liberal applications of farm manure or leguminous crops as green manures. It should be limed to correct acidity, and applications of superphosphate would undoubtedly prove of value.

#### MUCK (21a)

There is a small area of muck in the county, covering 0.1 percent of the total area. It occurs in small depressed areas, generally in the center of the Clyde silty clay loam areas. There is a small area along Walnut Creek one-half mile north of Ridgeway. Other small areas lie in Sections 6 and 8 of Madison Township and Section 7 of Jackson Township and Section 34 of Sumner Township.

The largest developments are found in Sections 22 and 23 of Orleans Township and in an old slough two miles east of Bluffton along the Upper Iowa River.

The surface soil of muck consists of a black finely divided vegetable material, containing some fibrous or peaty material in spots. The surface soil is 6 to 8 inches in depth and rests upon a black, plastic, tenacious silty clay to clay. The lower subsoil below 24 inches is often a grayish-brown or gray clay, mottled with brown and gray. The black clay usually extends to a depth of 36 inches, a grayish-brown clay being found at the outer edge of the area. In the area along Walnut Creek the surface soil is peaty and in the old slough east of Bluffton, the soil is swampy and peaty in character. Very little of the muck has been drained; most of it is used for pasture, and some wild hay is cut. The cultivated areas are used for corn and yield from 20 to 60 bushels per acre on the better decomposed and better drained areas. Small grains grow rank and are inclined to lodge.

For the agricultural utilization of areas of muck, the first treatment necessary is adequate drainage. After draining, it is desirable to seed down the area to timothy and alsike clover, or some similar crop, and pasture for several years to permit the further decomposition of the organic matter and provide for better soil conditions for the growth of general farm crops. Applications of phosphate fertilizers and, occasionally, of potash fertilizers may be advisable on these areas after they have been well drained and pastured for a number of years. Vegetable crops may be grown successfully on such areas, and, where these crops are produced, applications of fertilizing materials, such as superphosphate and muriate of potash, are desirable.

#### GENESEE SILT LOAM (71)

The Genesee silt loam is a minor type, covering 0.1 percent of the total area. It is found along the tributary of Turkey River south of Spillville in Section 19 of Calmar Township and also in Sections 11 and 12 of Bloomfield Township along the Yellow River and one of its tributaries. There are small areas in Sections 14 and 23 of Fremont Township. The largest area occurs in Sections 22 and 23 of Canoe Township along Canoe Creek.

The surface soil of the Genesee silt loam is a light-brown heavy silt loam extending to a depth of 15 inches. The subsoil is a light grayish-brown silt loam to light silty clay loam, containing considerable fine sand. In the areas in Sections 22 and 23 of Canoe Township and in Section 8 of Decorah Township along the Upper Iowa River, the soil is a yellowish-brown fine sand or sandy clay. The subsoil is a yellowish-brown fine sand or sandy clay, occurring at a depth of 30 to 34 inches. Occasionally a layer of light yellowish-brown fine sand 1 to 2 inches thick is found in the silty soil horizon.

Practically all of the soil is in cultivation, corn being grown almost exclusively. The yields of this crop amount to 25 to 50 bushels per acre. On the uncultivated areas the type is used for permanent pasture which consists of bluegrass mixed with white clover. When the type is cultivated, it will respond to applications of farm manure and the turning under of leguminous green manure crops. It is acid in reaction and should be limed for the best crop growth. The application of a phosphate fertilizer would be of value, and tests of superphosphate are recommended.

### RESIDUAL SOILS

There are two residual soils classified in the Boone and Dubuque series, and these, with the areas of rough stony land, make a total of three residual soil areas. Together they cover 6.0 percent of the total area.

#### ROUGH STONY LAND (78)

A considerable area of rough stony land, amounting to 5.6 percent of the total area is found in this county. The greater part of this land occurs along the Upper Iowa River and extends back along the tributaries from one to six miles. There is also a considerable area along Canoe Creek and Paint Creek and up their tributaries. Only a few scattered strips are found along the bluffs adjacent to Turkey River.

Rough stony land comprises the steep and abrupt slopes adjacent to the streams which have cut deeply into the underlying limestone. The type also includes the limestone ledges found along the larger streams, especially along the Upper Iowa River.

Small broken timber patches occur on this land in continuous strips a fourth of a mile to three miles long. The trees on the lower slopes are usually pine and cedar, with a belt of birch trees extending up the slopes. At the top and skirting the border of the uplands are strips of hardwoods, mostly oak, and patches of underbrush. Small scattered hazel thickets cover the gentler slopes along the tributary streams. In a few places narrow strips of cultivable soil, 20 to 30 feet in width, are located along the extreme lower slopes. Except for these strips, the land is utilized only for grazing purposes.

#### BOONE FINE SANDY LOAM (210)

The Boone fine sandy loam is a minor type, covering 0.3 percent of the total area. It occurs in a number of small areas, the largest being found one-half mile east and northeast of Freeport. Other areas occur in Sections 7, 8 and 18 of Highland Township, in Section 11 of Hesper Township, in Section 31 of Calmar Township, in Section 6 of Washington Township, in Sections 1, 2, 7, 8 and 17 of Glenwood Township and in Sections 1, 3, 4, 14, 20 and 29 of Pleasant Township. Small areas occur along Trout Run in Decorah Township. Strips are mapped below the rough stony land along the lower slopes on the upper fork of Canoe Creek and along the Upper Iowa River between the upper dam and the lower dam.

The surface soil of the Boone fine sandy loam is a light brown to medium dark brown fine sandy loam, extending to a depth of 6 inches. The subsoil is a light yellowish-brown fine sand to very fine sand, grading at 15 inches into a pale yellow, fine to very fine sand, appearing almost white when dry. The St. Peter's sandstone, the parent rock from which the soil is derived, is exposed in many places in the northern half of the county and is whitish or pale yellow in color. The soil is variable in depth, ranging from 3 to 4 inches at the upper part of the slope to 2½ to 4 feet towards the base. It is found on the lower slopes adjacent to the streams and on the slopes of residual limestone ridges.

The type is of minor importance agriculturally, owing to its small extent, and is mostly utilized for pasture purposes. The large area on the high upland ridge east and northeast of Freeport is cultivated and general farm crops are

grown. Yields are much the same on this area as those secured on the Carrington loam. It will respond to the same treatments as that type. The other areas support a growth of grass and are used for pasture purposes.

#### DUBUQUE SILT LOAM (183)

The Dubuque silt loam is a minor type in the county, covering only 0.1 percent of the total area. The largest development is found in Section 17 of Madison Township. Others occur in Sections 19 and 20 of Calmar Township east of Spillville, in Sections 19 and 20 of Calmar Township, in Section 30 of Bluffton Township and in Section 7 of Springfield Township. Several areas too small to map are scattered thru Sections 24 and 30 of Bluffton Township.

The surface soil of the Dubuque silt loam is a grayish-yellow or light yellowish-brown silt loam, extending to a depth of 6 to 8 inches and resting on sandstone or limestone. Small areas of a deeper residual soil have been included with this type. In these areas the soil is a heavy brown silt loam to silty clay loam to a depth of 10 inches underlaid by a yellowish-brown tenacious clay. The subsoil layer rests on a limestone bed at depths of 18 to 30 inches. Variations from the typical soil occur in the extreme southwest corner of the county in Sections 19, 29 and 30 of Jackson Township on each side of Goddard Creek. There is a total area of less than 200 acres. The surface area of this variation from the typical soil is flat and there is a general slope toward the stream. Drainage of this area is good and the land is all under cultivation.

The typical soil is utilized for general farm crops, and fair yields are secured, altho the land is apt to be drouthy owing to the shallow surface soil. The type will respond to applications of farm manure to improve the water holding capacity, and the turning under of leguminous green manure crops would be of value. It is acid in reaction and should be limed for the best growth of legumes. Applications of phosphate fertilizers would be desirable. Tests of superphosphate are recommended.

# APPENDIX

## THE SOIL SURVEY OF IOWA

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

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

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

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested.

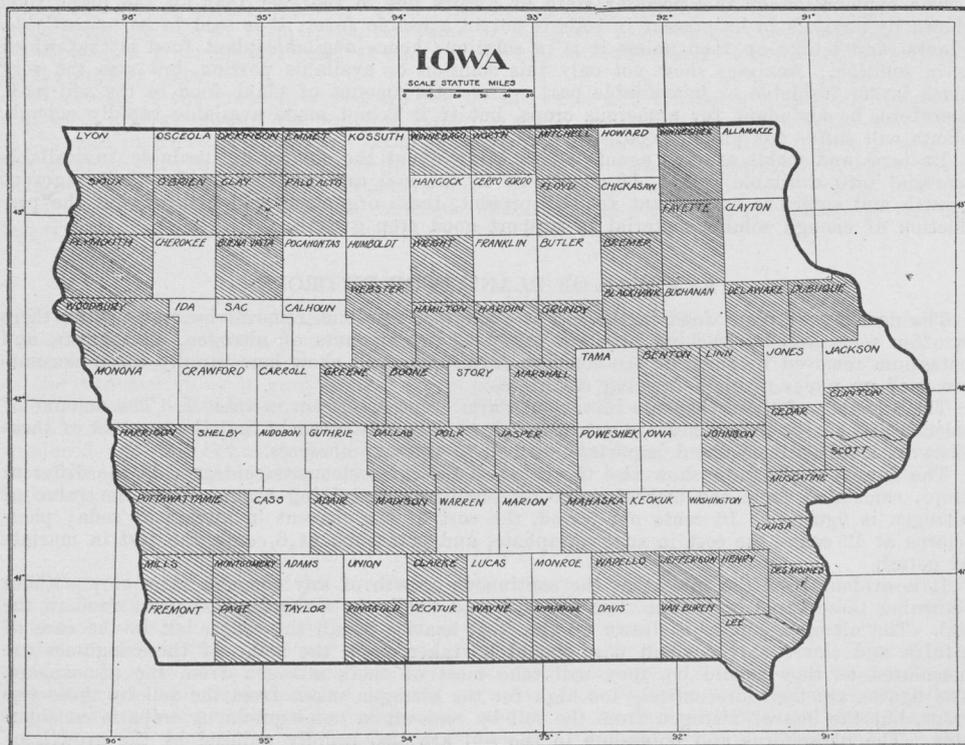


Fig. 19. Map of Iowa showing the counties surveyed.

### 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 solution or available portion, but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

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

#### REMOVAL OF PLANT FOOD BY CROPS

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

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

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

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

TABLE I. PLANT FOOD IN CROPS AND VALUE  
Calculating Nitrogen (N) at 16c (Sodium Nitrate ( $\text{NaNO}_3$ )), Phosphorus (P) at 12c (Superphosphate), and Potassium (K) at 6c (Potassium Chloride ( $\text{KCl}$ )).

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

manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

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

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

#### REMOVAL FROM IOWA SOILS

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

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

#### PERMANENT FERTILITY IN IOWA SOILS

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

Proper system 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 crop production, largely because they help control the moisture in the soil.

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

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

#### 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 of 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 proper rotations the time between two different crops of the same plant is long enough to allow the "toxic" substances 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 reasons 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, superphosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and superphosphate. 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 superphosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

#### LIMING

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

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as 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 areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 20.

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

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

Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of the 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 division may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

#### THE SOIL SURVEY BY COUNTIES

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

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

#### GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate

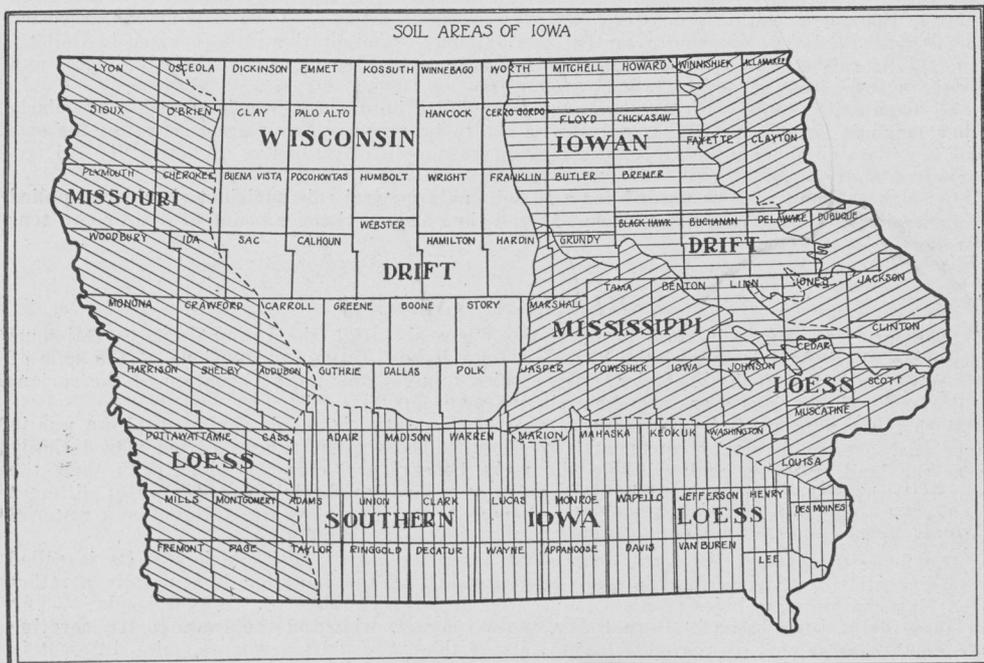


Fig. 20. Map showing principal soil areas in Iowa.

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 silt.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

*Gravels*—More than 50 percent very coarse sand.

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

#### METHODS USED IN THE SOIL SURVEY

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

\* 25mm equals 1 in. † Bureau of Soils Handbook.

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

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

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

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

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

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

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