SOIL SURVEY OF IOWA
O'BRIEN COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 43
June, 1926
Ames, Iowa

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By W. H. Stevenson and P. E. Brown with the assistance of H. R. Meldrum, L. W. Forman and W. G. Baker

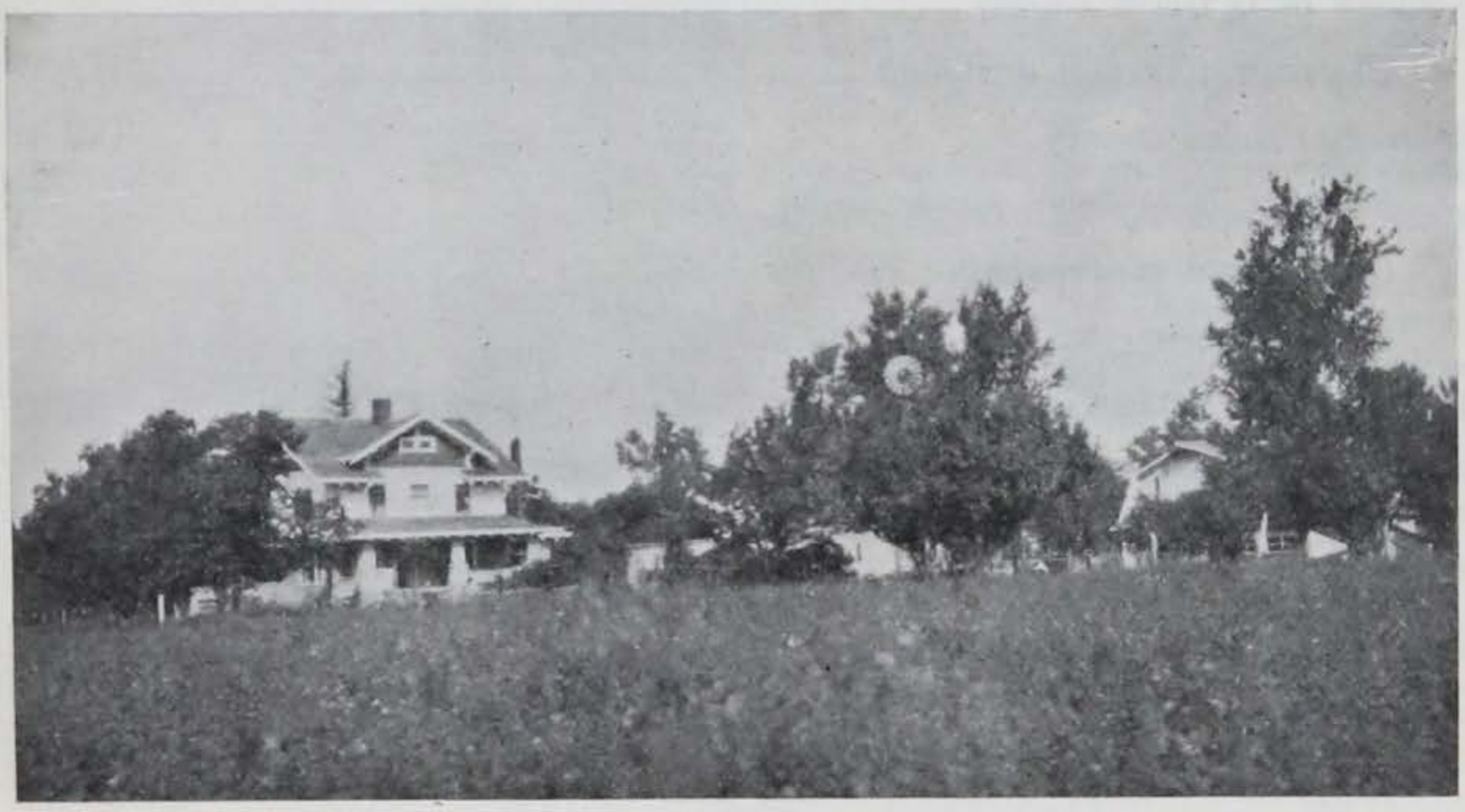


Fig. 1. Typical Farmstead in O'Brien County.

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

CONTENTS

O'BRIEN COUNTY SOILS*

By W. H. Stevenson and P. E. Brown with the assistance of H. R. Meldrum, L. W. Forman and W. G. Baker

O'Brien County is located in northwestern Iowa in the second tier of counties east of the South Dakota state line and in the second tier south of the Minnesota state line. It lies partly in the Wisconsin drift soil area and partly in the Missouri loess area. The soils of the county are mainly of loessial origin but a considerable area, particularly in the eastern part of the county, is of glacial origin.

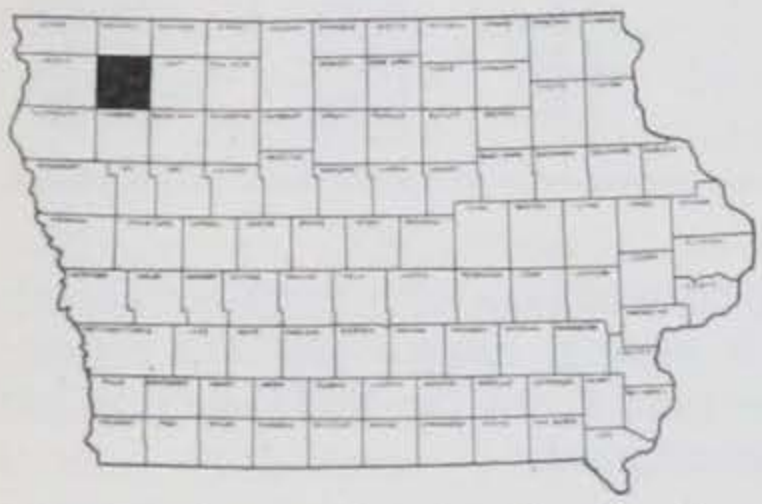


Fig. 2. A map showing the location of O'Brien County.

The total area of the county is 569 square miles or 364,160 acres. Of this area 352,940 acres or 96.9 percent is in farm land. The total number of farms is 1,918 and the average size of the farms is 184 acres. The farms are operated by 725 owners, 352 relative renters, 741 renters, 93 both owning and renting and 7 unclassified. The following figures from the Iowa Yearbook of Agriculture for 1923 show the utilization of the farm land in the county.

Acreage in general farm crops	260,959
Acreage in farm buildings, public highways and feed lots	19,191
Acreage in pasture	70,793
Acreage in waste land not utilized for any purpose	533
Acreage in farm woodlots used for timber only	104
Acreage in orchards	147
Acreage in crops not otherwise listed	324

THE TYPE OF AGRICULTURE IN O'BRIEN COUNTY

At present the type of agriculture practiced in the county consists mainly of a system of general farming, including the growing of corn, oats and hay, and the raising and fattening of hogs and beef cattle. Dairying and sheep raising are of minor significance. The income on the farms of the county is derived, in general, from the sale of corn and oats and the marketing of hogs and beef cattle. Probably about half of the corn crop is sold and a large part of the oats crop is similarly disposed of. Most of the hay and forage crops are utilized for feed on the farm. In individual cases, some of the minor crops grown serve to increase the farm income, and in many instances the sale of dairy products, of sheep and of poultry products adds considerably to the usual farm income.

The area in waste land in the county is rather large and a considerable proportion of this total area might be reclaimed and made productive thru the adoption of proper methods of soil treatment. The causes of the infertility of these areas are so variable that it is impossible to make general recommendations regarding treatment. In a later section of this report, methods of handling waste land will be suggested which will be desirable for use on unproductive areas of some of the individual soil types in the county.

*See Soil Survey of O'Brien County, Iowa, by J. A. Elwell of the U. S. Department of Agriculture and H. R. Meldrum of the Iowa Agricultural Experiment Station. Field Operations of the Bureau of Soils, 1921.

TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN O'BRIEN COUNTY, IOWA*

Crop	Acreage	Percent of total farm land of county	Bu. or tons per acre	Total bushels or tons	Average price	Total value of crop
Corn	133,290	37.76	45.0	5,998,050	$0.62	$3,718,791
Oats	90,107	25.53	44.0	3,964,708	0.37	1,466,941
Winter wheat	180	0.05	18.0	3,240	0.89	2,883
Spring wheat	56	0.01	14.0	784	0.87	682
Barley	7,292	2.06	33.0	240,636	0.52	125,130
Rye	40	0.01	15.0	600	0.66	396
Potatoes	956	0.27	83.0	79,348	0.77	61,097
Tame hay	20,424	5.78	1.5	30,636	12.50	382,950
Wild hay	6,169	1.74	1.4	8,636	10.50	90,678
Alfalfa	2,445	0.69	3.6	8,802	16.25	143,032
Pasture	70,793	20.05	....	.....	.....	.....

*Iowa Yearbook of Agriculture, 1923.

Often these treatments may be used on the infertile areas, with very beneficial results. Advice regarding the treatment of soils in special cases where the conditions seem to be more or less abnormal, may be secured from the Soils Section of the Iowa Agricultural Experiment Station, upon request.

CROPS GROWN IN O'BRIEN COUNTY

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

Corn occupies the largest area in the county, covering 37.76 per cent of the total farm land. Average yields of corn amount to 45 bushels per acre. In many cases where the conditions are more favorable, larger yields than this are frequently secured. The most popular variety grown is a yellow dent, known locally as the Armstrong Yellow Dent. White dent varieties are grown to some extent, Silver King being the most common. Probably about half of the corn grown in the county is utilized on the farms for feeding purposes. Some of it is used for silage. There were 163 silos in the county in 1923 and 15,270 tons of silage were produced. Corn is the leading cash crop, supplying a large part of the farm income in the county. It is sold thru the local elevators and disposed of mainly on the Chicago markets.

The second crop in acreage and value in the county is oats. This crop was grown, in 1923, on 25.53 per cent of the total farm land. Average yields in that year amounted to 44 bushels per acre. Under very favorable conditions the yields are higher. Mixed varieties seem to be grown the most commonly, the early and midseason varieties being about equally popular. Of the early varieties the Kherson and the Iowa 103, Iowa 105, Iowar and the Early Champion are the most popular. The leading midseason variety is the Green Russian. The greater part of the oats crop is used for feeding purposes but considerable quantities of oats are marketed, being sold on the Chicago markets.

The hay crop is the third in acreage and value in the county. The tame hay consisting chiefly of timothy and clover mixed, covers 5.78 per cent of the total farm land of the county. Wild hay is grown on 1.74 per cent of the county. Average yields of the tame hay amount to 1.5 tons per acre while the yields of the wild hay are slightly lower. Some timothy is grown alone in the county and some clover is grown alone. Both of these crops are utilized to some extent for seed, there being a production of 2,080 bushels of timothy seed from 484 acres in 1923 and a production of 371 bushels of clover seed from 233 acres in the same year. The wild hay consists principally of wild prairie grasses and its value, from the feeding standpoint, is much less than that of the tame hay. The

greater part of the hay crop in the county is used for feed. Occasionally, however, some surplus is sold on the local markets. Frequently it is necessary to ship hay in to meet the local demands.

Alfalfa is grown to some extent in the county and the crop is receiving increased attention as more is learned regarding its value and the methods which should be followed in securing a good stand. In 1923, it was grown on 2,445 acres in the county. Average yields amount to 3.6 tons per acre. The value of the crop is considerable and undoubtedly larger areas could be devoted to it with profit.

A considerable area in the county is devoted to barley. In 1923, this crop was grown on over 2 per cent of the farm land and with average yields amounting to 33 bushels per acre, the value of the crop was considerable. It is grown usually as a substitute for oats in the rotation. Barley is used mainly as feed for young stock but in many cases it serves as a cash crop. Potatoes are grown on practically all farms chiefly, however, for home consumption. In a few cases some of the surplus of this crop is sold on the local market. In general the production of potatoes in the county is quite inadequate to supply the local demand.

Wheat is a minor crop in the county, being grown on relatively a very small acreage. The winter wheat is grown more than the spring wheat. Average yields of winter wheat amount to 18 bushels per acre while the spring varieties yield at the rate of 14 bushels per acre. The entire wheat crop is marketed locally. The value of the wheat grown in the county is not large.

Other minor crops grown in the county include rye, buckwheat, flax, emmer and sorghum. Some mammoth red clover, alsike and sweet clover are grown on small acreages for forage crops. Some millet, rape and soybeans are also grown in the county in a small way.

Orchards are maintained on many farms and apples are the principal fruit grown. The Duchess and Wealthy are the most common varieties. There is generally an insufficient production of apples to meet the home demand. Small fruits including strawberries, raspberries and blackberries are grown on small areas. Sweet corn and popcorn are planted in small areas on a few farms. Garden crops are produced quite generally on the individual farms for home consumption and occasionally small quantities are sold on the local market.

O'BRIEN COUNTY'S LIVESTOCK INDUSTRY

The livestock industries of the county include hog raising, cattle raising and feeding, dairying, sheep raising and the raising of horses and mules. The following figures taken from the Iowa Yearbook of Agriculture for 1923, show the extent of the livestock industry in the county:

Horses, all ages	12,452
Mules, all ages	507
Swine on the farms July 1, 1923	152,753
Swine on the farms January 1, 1924	115,741
Cattle, cows and heifers kept for milk	13,228
Cattle, other cattle not kept for milk	33,749
Cattle, total all ages, January 1, 1924	46,977
Sheep, all ages, January 1, 1924	3,293
Sheep, shipped in for feeding 1923	1,454
Sheep, total pounds of wool clipped	12,555
Poultry, total, all varieties, January 1, 1924	273,796
Poultry, number dozen eggs received 1923	1,160,493

Hog raising is the most important livestock industry in the county. Jan. 1, 1924, there were 115,741 hogs on the farms. Most of the herds are of mixed breeds but in many cases purebreds are receiving special attention. The Duroc Jersey and big type Poland China are now the most popular breeds. Chester Whites are raised in considerable numbers. The breeding of Hampshire hogs

has been increased considerably in recent years. The hogs are shipped mainly to Chicago and Sioux City.

The raising of beef cattle is the second livestock industry of importance in the county. Jan. 1, 1924, there were 46,977 cattle on the farms. Of this number 33,749 were beef cattle, probably about 10 per cent of these being feeders, the rest home raised. At the present time cattle of mixed breeds predominate but purebreds are gaining in favor. The Shorthorn and Hereford breeds are equally popular and there are some herds of Angus. The beef cattle are marketed chiefly in Chicago and Sioux City and some are shipped to St. Paul.

Dairying is practiced to some extent in the county but the industry is only of local significance. In 1923, there were 13,228 head of dairy cattle on the farms. Four local creameries are supplied with cream mainly from the farms in the county. The dairy industry might be extended profitably in many cases throughout the county.

Sheep raising is practiced to a small extent in the county and some sheep are shipped in for feeding. Most of the sheep are kept mainly for wool production. The Shropshire breed is the most popular. The sheep industry as a whole is of minor significance in the county.

Some horses and mules are raised in the county, chiefly to provide work stock for the farms. Among the horses the Percheron, Belgian, Shire and Clyde breeds are the most common, the Percheron being the most popular.

Flocks of poultry are maintained on practically all farms in the county and the value of the poultry products is considerable, practically all being sold to the county marketing agencies. More attention to the poultry industry would undoubtedly lead to a larger farm income from this source.

THE FERTILITY SITUATION IN O'BRIEN COUNTY

The yields of general farm crops grown in O'Brien County are usually quite satisfactory, but proper methods of soil treatment will effect profitable increases in many cases. The particular needs of the individual soil types mapped in the county are given in detail in a later section of this report. Attention may be called, however, to certain general recommendations which may be given regarding the needs of the soils of O'Brien County.

The drainage conditions in the county are not entirely adequate in all cases altho in general the soils are fairly well drained. In some areas, however, the conditions would be improved considerably for crop growth by the installation of tile. On many areas in the county where the land is too wet, tiling will prove of profit.

While many of the soils of the county are very well supplied with organic matter and dark in color, many experiments and much experience have shown that additions of fertilizing materials supplying organic matter will be of large value on the various types. Many of the upland soils, particularly the Marshall silt loam, will respond very profitably to applications of farm manure. Liberal amounts of this material should be employed. In many instances, leguminous crops may profitably be used as green manures, particularly where the supply of farm manure is limited. All the crop residues produced on the farm should be thoroly utilized to aid in keeping up the supply of organic matter.

Many of the individual soil types in the county are acid and in need of lime. In some cases the soils are well supplied with lime and in such instances liming is unnecessary. It is important, however, that the soils be tested regularly for reaction or lime requirement, in order that they may be kept in the best condition for the growth of general farm crops and particularly for the best growth of leguminous crops. The only way to learn whether or not the soil is acid and in need of lime is to have it tested. It is recommended, therefore, that the soils

in O'Brien County be tested regularly for lime requirement in order that they may be kept well supplied with this constituent.

The soils of the county are generally rather low in phosphorus and additions of a phosphate fertilizer would undoubtedly be of value in many cases. The experiments which have been carried out with rock phosphate and acid phosphate have indicated large returns from the use of these fertilizers in many instances on some of the soil types found in this county. In many cases, acid phosphate has proven of considerable value. In some other instances, rock phosphate has shown up very well. Definite recommendations regarding the use of acid phosphate or rock phosphate cannot be given at the present time inasmuch as the two materials seem to prove of different value under differing conditions. It is recommended, therefore, that both phosphates be tested on individual farms in order to determine which material will prove the most profitable under the particular conditions.

Complete commercial fertilizers are not recommended for general use in O'Brien county at the present time inasmuch as it is believed that acid phosphate will prove of quite as large value and it is much less expensive. Tests of complete fertilizers may be carried out, however, on individual farms and if profitable returns are secured from their use, then there is no objection to their application. Commercial nitrogenous fertilizers are not needed in the county because leguminous crops used as green manures prove a cheaper and better source of nitrogen for the soils deficient in this element. In order to keep up the supply of nitrogen the thoro utilization of farm manure, some turning under of legumes as green manures and the use of all crop residues, will prove sufficient.

Erosion occurs to some extent in the county and wherever this injurious action takes place, it is desirable that some method be adopted to prevent the further washing away of the surface soils and the formation of gullies or to reclaim the land which has already been injured in these ways. Suggestions are offered later in this report for the control and prevention of erosion and from these suggestions some method may be chosen which will be suitable for any particular conditions.

THE GEOLOGY OF O'BRIEN COUNTY

The geological history of O'Brien County is significant only insofar as it involves the glacial age and the succeeding loessial period. Inasmuch as the bedrock material underlying the present soils of the county is so deeply buried by the subsequent deposits of glacial drift and loessial material in later ages, there is no effect of these rock materials on the soils of the county.

At least twice during the glacier age, a great glacier swept over the county and upon its retreat left behind vast masses of debris or glacial till. In many cases the earlier glacial deposits were carried away to a large extent by the later glaciers and the earlier topographic features of the county, which were established preceding the first glacier and following the first glaciation, were largely obliterated by the succeeding action of the later glaciers.

The first ice sheet, known as the Kansan, left behind a deposit of a drift material consisting chiefly of a blue clay containing numerous pebbles, boulders and fragments of shale and frequently much sand and gravel. The depth of this Kansan drift sheet was extremely variable, ranging from 10 to 50 feet, the deeper areas occurring where previously there had been valleys or depressions in the uplands. After weathering, the Kansan drift changed in color to a brown or yellow and with the addition of organic matter became darker. The influence of this early glaciation upon the soils of the county is of very minor significance. Only in the case of the Dickinson fine sandy loam is there any evidence of the

Kansan material even in the subsoil. There is even some question regarding the origin of the subsoil material in the Dickinson series but it is assumed to be of Kansan origin.

At a later date, a second glacier swept down from the north and upon its retreat covered the county with a thick layer of drift. This deposit is known as the Wisconsin drift. In its unweathered condition, it is a bluish-drab to bluish-gray in color becoming yellow or buff to gray when slightly weathered. It consisted of a mass of clay, sand and gravel and probably was originally very highly calcareous. It contains more pebbles and boulders than the earlier Kansan till and is somewhat darker in color. Since its deposition, the drift material has been largely modified by weathering, by the accumulation of organic matter and also by the leaching out of lime which has taken place to a very large extent in many areas. The soils in a narrow strip along the eastern boundary of the county have been derived from this Wisconsin glaciation. The types distinguished in this area include the Clarion silt loam, the Carrington silt loam, the Webster silty clay loam, the steep phase of the Clarion loam and probably a part of the Dickinson fine sandy loam. The terrace and bottomland soils on the eastern edge of the county are also undoubtedly partly formed from glacial material.

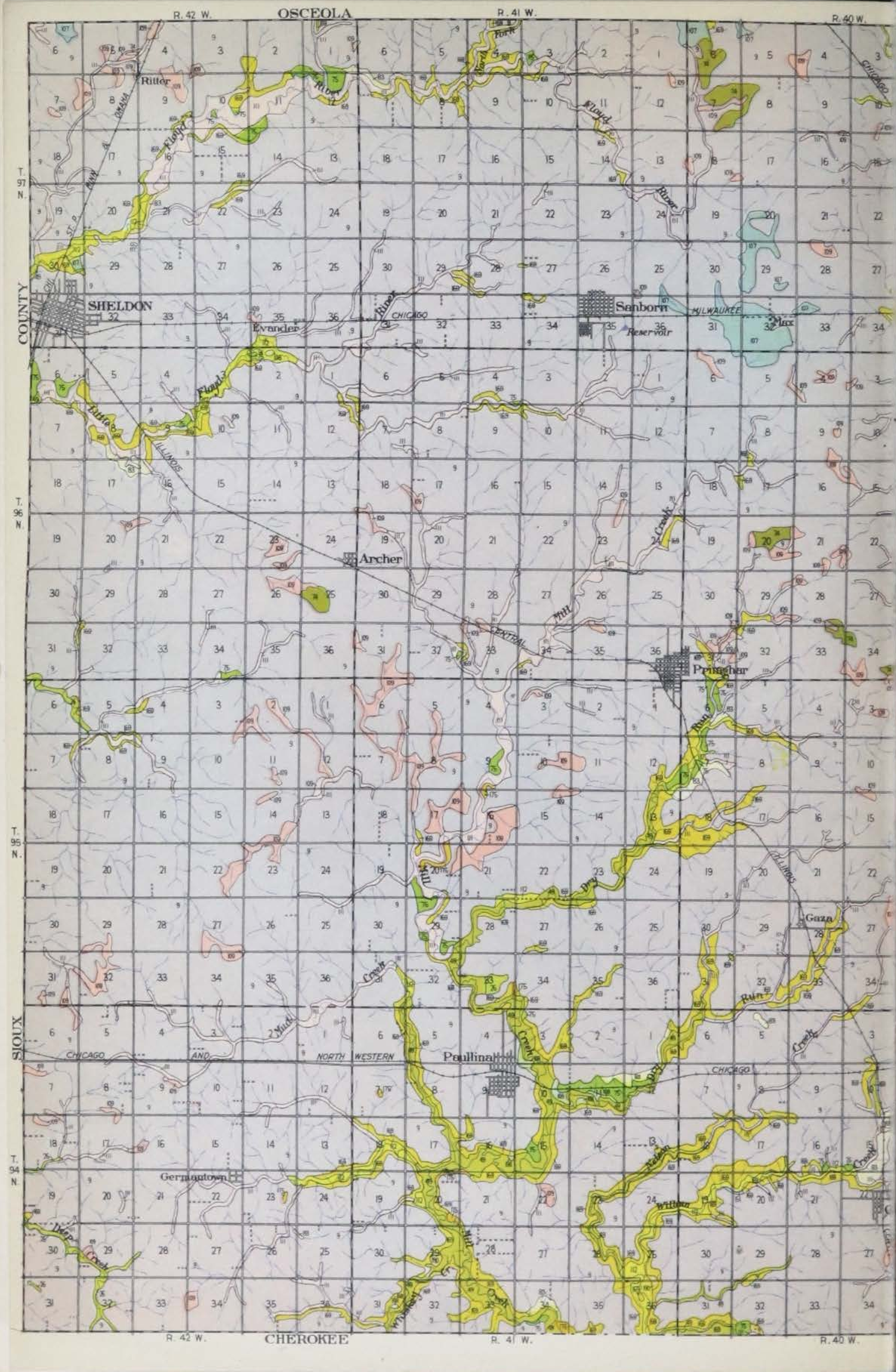
At a later date when climatic conditions were very different than at present there was laid down over the Wisconsin drift, in the western part of the county, extending to within 7 miles of the eastern boundary, a layer of silty material known as loess. This consists naturally of a yellowish or grayish-yellow silty material quite uniform in texture and composition and originally containing a high percentage of calcareous material. The thickness of this loess deposit is extremely variable. It was probably laid down quite uniformly over the surface of the land. But in many areas considerable washing has taken place and the surface soil is thinner where it occurs on the tops of former knolls and ridges. Then, too, there has been a filling up of the lower lying areas with the loess washed down from above. In general the loessial covering will vary from a few feet in depth to 10 to 20 feet on the deeper areas.

During the processes of weathering to which the loess has been subjected, there has been a washing out of the calcareous material until now it is generally lacking in lime, at least thruout the three foot section. Accumulations of organic matter have occurred from the growth of vegetation and the surface soil of the loess has been darkened and it is now characteristically a dark brown to black in some areas. The Marshall silt loam, the most extensive upland type in the county and the flat phase of the same type, are derived from this loessial deposit. Together they cover almost three-fourths of the total area of the county.

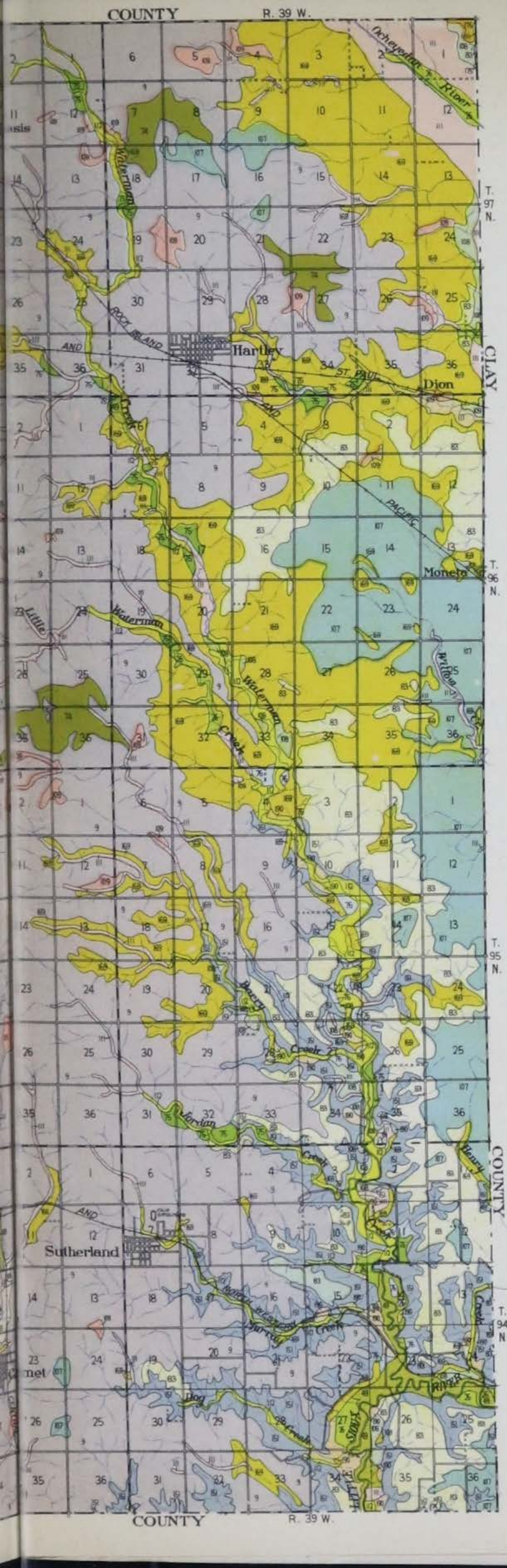
Much of the material constituting the terraces and bottomland soils in the loessial section of the county, are also undoubtedly of loessial origin. This is particularly true in the case of the Judson loam on the terraces. It is derived almost entirely from the loessial material carried down from the Marshall silt loam on the upland. In fact, it may be stated rather definitely that the terrace and bottomland soils in the county are made up very largely from loessial material, there being in some cases some admixture with drift material from the underlying drift deposits. In the eastern part of the county, the mixture of drift materials has been washed down into the bottoms from the uplands which are derived from glacial material.

PHYSIOGRAPHY AND DRAINAGE

The prevailing topography of the county is level to undulating. This is the characteristic topographic condition of the loess covered uplands which occur over the major portion of the county. The undulating topography is character-



OSCEOLA
R. 42 W.
R. 41 W.
R. 40 W.
T. 97 N.
T. 96 N.
T. 95 N.
T. 94 N.
SIOUX COUNTY
CHEROKEE
SHELDON
Ritter
Evander
Sanborn
Reservoir
Archer
Primghar
Gaza
Paullina
Germantown
Floyd River
North Fork
Little Floyd
Mill Creek
Dry Run
Nelson Creek
Willow
Deep Creek
Mud Creek
Whiskey Cr.
CHICAGO
MILWAUKEE
ILLINOIS CENTRAL
CHICAGO AND NORTH WESTERN
OMAHA



SOIL MAP OF O'BRIEN COUNTY, IOWA

Thomas D. Rice, Inspector Northern Division

Soils surveyed by J. A. Elwell, in charge U. S. Department of Agriculture and H. R. Meldrum, Iowa Agricultural Experiment Station

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS

Milton Whitney, Chief. Curtiss F. Marbut, in charge of Soil Survey

IOWA AGRICULTURAL EXPERIMENT STATION

C. F. Curtiss, Director. W. H. Stevenson, in charge Soil Survey

P. E. Brown, Associate in charge.

LEGEND

Drift Soils

169 — Clarion silt loam

83 — Carrington silt loam

107 — Webster silty clay loam

151 — Clarion loam (steep phase)

175 — Dickinson fine sandy loam

Loess Soils

74 — Marshall silt loam (flat phase)

9 — Marshall silt loam

Terrace Soils

109 — Fargo silty clay loam

75 — Waukesha silt loam

108 — O'Neill loam

190 — Judson loam

76 — Sioux loam

Swamp and Bottomland Soils

111 — Lamoure silty clay loam

112 — Lamoure loam

48 — Wabash loam

26 — Wabash silt loam

The above signs are in current use on the soil maps. Variations from this usage appear in some maps of earlier dates.

istic in all parts of the loessial upland in the county, except in the northwestern quarter of Baker Township, in the northern part of Dale Township, in the western part of Lincoln and Hartley Townships, and in Floyd Township near Ritter. In the southern tier of townships the topography is moderately rolling, particularly along the Floyd River in Franklin Township and in Floyd Township and in the northern part of Carroll and Summitt Townships. Along the west bank of Waterman Creek and its main tributaries to the west narrow strips of land occur which are rolling to hilly in topography. In the southern part of Grant and Waterman Townships the areas of rougher land along the creeks are somewhat wider and the slopes to the creeks are steeper.

In general the rolling to hilly land occurs in the county only along the main drainageways. The valleys of the Little Sioux River and the lower courses of both Waterman and Mill Creek are narrow almost gorge-like in places. The upland rises from the deeper valleys with steep abrupt slopes and there are only narrow stripes of colluvial and alluvial material at the base of the slopes. Along the smaller streams thruout the county and especially along the minor tributaries, the slopes to the streams are gradual and make the upland appear gently undulating in topography.

In the extreme eastern part of the county, east of Waterman Creek, there is an area of an almost level drift plain bordered by Waterman Creek on the west and on the north by the drainageways which flow into Clay County. This more or less level plain consists mainly of the Webster silty clay loam, an important drift type in the county.

The land elevation in the county is the highest along the divide which extends from eastern Franklin Township in a southeasterly direction as far as Gaza. From this divide the land slopes gently to the west, southeast and northeast. Generally the greatest slope is from the divide at Gaza southeast thru Waterman Township to the corner of the county.

The drainage of the county is brought about by the Little Sioux River, the Ocheyedan River, Mill Creek, Floyd and Little Floyd Rivers and their tributaries. The Little Sioux River is the largest stream flowing thru the county but only five miles of its course is in the county in the extreme southeastern corner of Waterman Township. Its chief tributary is Waterman Creek, which with its tributaries, Murray Creek, Jordan Creek, Barry Creek, and Little Waterman Creek, drains the four eastern townships and parts of Lincoln and Center Township. The level plain east of Waterman Creek in Omega and Grant Townships has practically no natural drainage. In the northern townships traversed by this stream, the drainage is very poorly developed and the upper courses of Waterman Creek are much like a sluggish prairie slough. The Ocheyedan River cuts across the northeast corner of the county, draining a very small area. There is little development of tributary streams and very little natural drainage from the adjacent uplands to this river.

The central, south central and southwestern parts of the county are drained by Mill Creek. The chief tributaries of this creek are Willow Creek, Nelson Creek, Dry Run and Mud Creeks. A part of the area traversed by Mill Creek and its tributaries is fairly well drained but in Baker and Summitt Townships and at the head of the creek itself in Center Township, the drainage is very imperfectly developed. In Union Township, Mill Creek flows thru a valley cut 35 to 50 feet into the upland. Along the upper course of the creek, however, the stream is very shallow, the valley is narrow and the river appears little more than a prairie slough.

The Floyd and Little Floyd Rivers provide the drainage for the northwest and north central parts of the county. In Floyd Township, the river is 25 to 30 feet below the uplands. Toward the east the valley gradually becomes narrower and shallower until, in Lincoln Township, the river is little more than a

slough. There is very little development of tributary streams to the Floyd and Little Floyd Rivers and the natural drainage of much of the area adjacent to these streams is very poorly developed.

The stream valleys along the Little Sioux River and Waterman Creek in Grant and Waterman Townships are 150 feet below the uplands in some cases. Towards the north the valley of Waterman Creek becomes narrower and shallower. The valley of the Ocheyedan River in Hartley Township is about 35 to 50 feet below the uplands.

The natural drainage system of the county is indicated in the accompanying map. It is apparent that while the drainage is quite adequate in parts of the area, considerable areas need artificial drainage. The level areas of drift upland in the eastern part of the county particularly need artificial drainage. In many areas in the central and particularly the north central part of the county drainage is quite imperfectly developed and the installation of tile there would be of very large value.

There are several areas of swamp and bottomland soils in the county and a number of areas of terrace soils. These are usually found in narrow areas along the rivers and tributary streams thruout the county. The Fargo silty clay loam

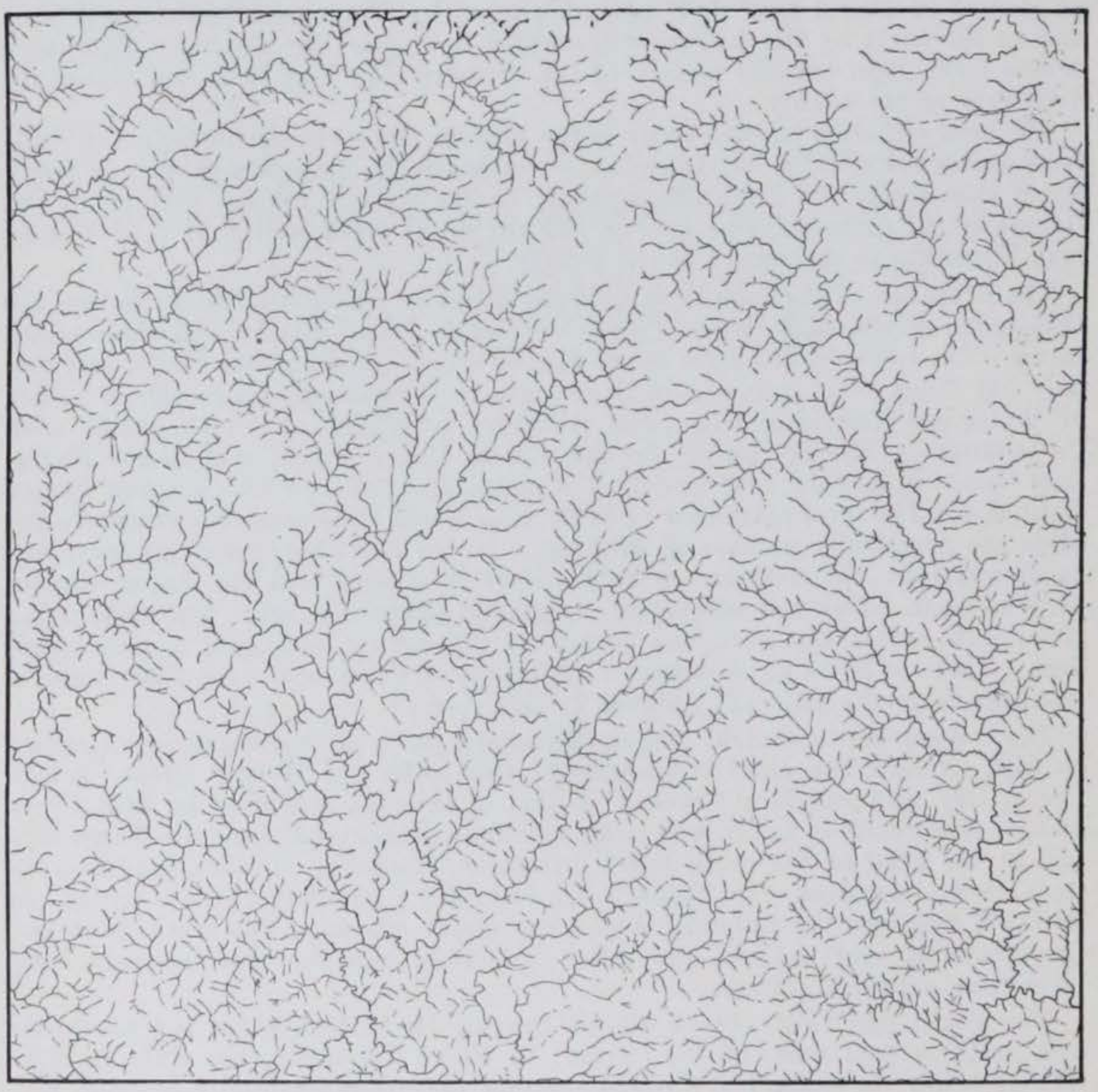


Fig. 3. Map of natural drainage system of O'Brien County.

is found mainly, however, in depressed areas in the upland at the heads of drainageways or on low flat divides. Some areas of the type also occur on gentle slopes to the uplands and in a few cases they are found on real terraces. The bottomland soils of the county are subject to overflow and are in general poorly drained. The terrace soils are fairly well drained with the exception of the Fargo silty clay loam. This type is particularly in need of drainage and in many cases the adjacent areas of much land are likewise in need of drainage. The bottomland soils must be protected from overflow before drainage would have any particular value.

In general it may be said that the need for drainage in this county is definitely evidenced in the flat phase Marshall silt loam, the Webster silty clay loam, the Fargo silty clay loam on the terraces and the Lamoure silty clay loam, the Lamoure loam, the Wabash loam and the Wabash silt loam on the bottoms.

THE SOILS OF O'BRIEN COUNTY

The soils of O'Brien County are grouped into four classes according to their origin and location. These are drift soils, loess soils, terrace soils and swamp and bottomland soils. Drift soils are formed from the material carried by glaciers and deposited on the surface of the land when the glacier retreated. They are variable in composition and contain pebbles and frequently boulders. Loess soils are fine dust-like deposits made by the wind at some time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them or by a depression of the river channel. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams and they are subject to more or less frequent overflow. The extent and occurrence of these groups of soils in O'Brien County are shown in table II.

By far the largest portion of the county, almost three-fourths of the total area, is covered by the loess soils. The actual per cent of the county covered by the Marshall silt loam and the flat phase of this type amounts to 72.8 per cent. The drift soils are minor in area, covering 16.7 per cent of the total area of the county. The terrace types are the smallest of all the soils of the county, covering only 3.2 per cent of the total area. The bottomland soils occur more extensively, being found on 7.3 per cent of the county. They are found occurring along practically all of the streams of the county in narrow irregular shaped areas.

There are 15 individual soil types in the county and these with the flat phase of the Marshall silt loam make a total of 16 soil areas. There are five drift soils, two loess soils including the flat phase of the Marshall silt loam, five terrace soils and four areas of swamp and bottomland. The various soil types in these groups are distinguished on the basis of certain definite characteristics which are described in the appendix to this report and the names indicate certain definite group characteristics. The areas covered by the various soil types in the county are given in table III.

The Marshall silt loam is the most extensive individual soil type in the county. With the flat phase which is very minor in extent, it covers 72.8 per cent of the county. It is the only loess type mapped in the area. The Clarion silt loam is the second most extensive soil type in the county and the largest drift soil. It covers 7.8 per cent of the total area. The Carrington silt loam is the second most extensive drift soil in the county and the fourth type in area. It covers 3.3 per cent of the county. The Webster silty clay loam is the third drift type and the fifth in area in the county, covering 3.2 per cent of the area. The Clarion loam steep phase is the fourth largest drift soil and the sixth type in extent, covering 2.3 per cent of the county. The Dickinson fine sandy loam, the remaining drift soil, is of very minor occurrence, covering only one-tenth

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN O'BRIEN COUNTY

Soil Group	Acres	Percent
Drift soils	60,928	16.7
Loess soils	264,960	72.8
Terrace soils	11,328	3.2
Swamp and bottomland soils	26,944	7.3
Total	364,160	....

of a per cent of the total area of the county. The Fargo silty clay loam is the most extensive terrace type and the seventh largest soil area, covering 1.7 per cent of the county. The Waukesha silt loam, the O'Neill loam, the Judson loam and the Sioux loam are all minor types in the county, each covering less than one per cent of the total area. The Lamoure silty clay loam is the most extensive bottomland soil in the county and the third largest soil type. It covers 4.6 per cent of the total area. The Lamoure loam is the second largest bottomland soil. It covers 1.3 per cent of the county. The Wabash loam is third in area, covering 1.1 per cent of the county. The Wabash silt loam is minor in area, covering only 0.3 per cent of the total area of the county.

In topography, the upland soils of the county vary considerably, ranging from the areas which are mapped as steep phase Clarion loam, which as the name indicates are rugged to rough and abrupt in topography, to the level stretches of the Webster silty clay loam in the eastern part of the county and the almost level areas of the flat phase Marshall silt loam in the western part of the county. The typical Marshall silt loam is gently rolling to undulating while the Clarion silt loam and Carrington silt loam are more strongly rolling thruout most of the areas of these types. The Dickinson fine sandy loam is even more rolling in topography than the Carrington and Clarion soils. On the terraces and bottoms the topographic features are not definitely developed and most of

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN O'BRIEN COUNTY

Soil No.	Soil Type	Acres	Percent of total area of county
	DRIFT SOILS		
169	Clarion silt loam	28,544	7.8
83	Carrington silt loam	12,032	3.3
107	Webster silty clay loam	11,648	3.2
151	Clarion loam (steep phase)	8,448	2.3
175	Dickinson fine sandy loam	256	0.1
	LOESS SOILS		
9	Marshall silt loam	262,080)	
74	Marshall silt loam (flat phase)	2,880)	72.8
	TERRACE SOILS		
109	Fargo silty clay loam	6,336	1.7
75	Waukesha silt loam	2,176	0.6
108	O'Neill loam	1,344	0.4
190	Judson loam	960	0.3
76	Sioux loam	512	0.2
	SWAMP AND BOTTOMLAND SOILS		
111	Lamoure silt clay loam	16,832	4.6
112	Lamoure loam	4,864	1.3
49	Wabash loam	4,032	1.1
26	Wabash silt loam	1,216	0.3
	Total	364,160	....

the areas are level to flat in topography, the terraces occasionally showing a slight slope to the streams or to the bottomlands.

THE FERTILITY IN O'BRIEN COUNTY SOILS

Samples were taken for analysis from each of the soil areas in the county except the steep phase Clarion loam. This type was not sampled because of its small extent, its little importance agriculturally and because its variable character of material would make an analysis of little value.

The more extensive soil types were sampled in triplicate but only one sample was taken from each of the minor types. The samplings were made with the greatest care in order that the samples should be representative of the particular soil type and that any variations due to previous treatment might be eliminated. The samples were taken at three depths, 0-6 2/3 inches, 6 2/3 to 20 inches, and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil, respectively.

The samples were all analyzed for total phosphorus, total nitrogen, total organic carbon, total inorganic carbon, and limestone requirement. The official methods were followed in the determination of the phosphorus, nitrogen and carbon and the Truog qualitative test was used in determining the limestone requirement. 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 4 or 12 determinations.

THE SURFACE SOILS

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

The phosphorus content in the various soil types is somewhat variable, ranging from 983 pounds in the Dickinson fine sandy loam on the drift upland up to 1,912 pounds in the Wabash silt loam on the bottoms. No very definite evidence exists of any relationship between the phosphorus content of these soils and the various soil groups, altho it does seem that the terrace soils and the swamp and bottomland types are somewhat better supplied than the upland drift and loess soils. This may be due to the fact that the alluvial soils have been cropped less and hence have lost less phosphorus. No noticeable difference is evidenced between the phosphorus content of the drift soils and of the loess types. The relationships among the individual soil types are, however, much more definitely indicated.

Some comparisons may be made among the various soil series which are represented in the county. Thus it is evident that the Webster silty clay loam on the drift uplands is richer in phosphorus than the types of the Clarion, Carrington and Dickinson series. Furthermore, the Clarion and Carrington soils are better supplied than the Dickinson types. On the terraces the O'Neill and Judson soils are richer in phosphorus than the other terrace types. The Fargo is better supplied than the Waukesha and Sioux soils. The differences here are rather interesting inasmuch as the Fargo soils are usually much better supplied than the other terrace types, and in this case the soil is surpassed by the O'Neill and Judson soils. Probably there is some peculiarity of the particular sample of Fargo which was analyzed in this work. The results for the O'Neill and Judson soils, however, seem to be a little high and perhaps these types are a little higher than would be usual. On the bottoms, the Wabash soils seem to be richer in phosphorus than the Lamoure types altho the difference is not great except in the case of the Lamoure loam.

In general the indications from previous observations along this line are borne out by the results given in the table. It would seem that the variations in phosphorus content, reflect certain characteristics which are used as the basis for

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

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
169	Clarion silt loam.....	1,144	6,640	77,662	....	4,000
83	Carrington silt loam.....	1,198	6,120	68,670	....	8,000
107	Webster silty clay loam.....	1,347	7,780	84,175	3,025	....
175	Dickinson fine sandy loam..	983	2,260	26,160	....	1,000
	LOESS SOILS					
9	Marshall silt loam.....	1,171	5,740	65,672	....	2,500
74	Marshall silt loam (flat phase)	1,158	6,200	74,937	....	2,000
	TERRACE SOILS					
109	Fargo silty clay loam.....	1,562	8,160	90,197	....	....
75	Waukesha silt loam.....	1,320	5,380	66,762	....	4,000
108	O'Neill loam	1,885	5,740	63,220	....	3,000
190	Judson loam	1,885	3,820	52,865	....	2,000
76	Sioux loam	1,306	3,820	47,528	18,417	....
	SWAMP AND BOTTOMLAND SOILS					
111	Lamoure silty clay loam....	1,751	11,100	134,450	26,325	....
112	Lamoure loam	1,347	4,240	52,974	7,521	....
49	Wabash loam	1,818	5,420	68,942	....	1,000
26	Wabash silt loam	1,912	5,520	72,485	....	1,000

distinguishing the various soil series. The relation may probably be traced to a number of characteristics, among which may be mentioned topography, color, and subsoil character. Thus the soils which are more level to flat in topography, blacker in color and have heavier subsoils will tend in general to be richer in phosphorus than the types which are lighter in color, more rolling in topography and have less impervious subsoils. As has been noted, there is an exception to this general statement in the case of the O'Neill soils on the terrace of this county, as ordinarily they would be expected to contain less phosphorus than the soils having heavier subsoils. In general, however, the relationship between the soil series and the phosphorus content is rather definitely indicated.

The relationship between phosphorus content and texture is very much more distinct, however, in all the previous comparisons which have been made. Unfortunately in this county the uplands and terrace types are all of different series, hence it is not possible to make any comparisons of the effect of soil texture within series. On the bottomlands the Lamoure silty clay loam is richer in phosphorus than the Lamoure loam. The Wabash silt loam is better supplied than the Wabash loam. The evidence secured from these analysis bears out, therefore, previous observations along this line, in indicating that fine textured types are generally better supplied with phosphorus than coarse textured soils. Thus silty clay loams are better supplied with phosphorus than silt loams, loams and sandy types. Silt loams are usually richer in phosphorus than sandy or fine sandy types of the same series. Apparently the texture of the soil may be of large significance in determining the content of phosphorus, and certainly the textural relationship is quite as important as the relationship evidenced on the basis of the characteristics which serve to distinguish the various soil series.

From the analyses of all of these soils, it is quite evident that phosphorus is deficient in the soils of O'Brien County. The supply is certainly not large enough to meet the needs of crops for very many years and in fact it would seem that phosphorus fertilizers would undoubtedly prove of value on many of these soils at the present time. When the supply of phosphorus in the soil goes below 1,200 pounds per acre, as is the case with practically all of the upland types in this county, it is quite certain that there is an insufficient supply of available phos-

phorus to meet the needs of plants. The evidence secured from greenhouse experiments and certain field tests on the same types in other counties has indicated very definite profits from the use of phosphorus fertilizers on the soils of this county.

The nitrogen content of the soils of the county varies quite as widely or even more than the phosphorus. The range in nitrogen content is from 2,260 pounds in the Dickinson fine sandy loam up to 11,100 pounds in the Lamoure silty clay loam. Again no very definite evidence exists of a relationship between the nitrogen content of the soil and the various soil groups. The terrace and bottomland types seem to be a little better supplied on the average than the upland soils but the differences are not very distinct. The drift soils and loess soils are about equal in nitrogen content. The alluvial soils might be expected to be a little higher in nitrogen because of the lack of plant growth and the poorer drainage conditions, both of which have tended to maintain the supply of nitrogen. The relationships, however, between nitrogen content and the various soil types are more definitely indicated and no conclusions can be drawn regarding the relationship to the soil groups.

Considering the various series of soils which are represented in the county, it is interesting to note that there is a rather definite relationship between the characteristics of the soil series and the content of nitrogen in the various types. Thus the Webster silty clay loam is richer in nitrogen than the other drift soils on the uplands. The Clarion and Carrington soils are better supplied than the Dickinson. On the terraces the Fargo silty clay loam is richer in nitrogen than the other terrace types. The Waukesha and O'Neill are better supplied than the Judson and Sioux. On the bottoms the Lamoure soils are richer in nitrogen than the Wabash types.

There is apparently some relationship between the nitrogen content of a soil and the various characters which serve to determine the soil series. Those series which are darker in color in the surface soil, more level in topography and have heavier textured subsoils seem to be better supplied with nitrogen than the lighter colored soils which are more rolling in topography and have lighter textured subsoils. The comparison is very obvious in the case of the Webster on the drift uplands as this is black in color, level in topography, and has a heavy textured subsoil. Similar comparisons can be made on the terraces as the Fargo types are blacker in color, more depressed in topography and heavy in subsoil character. The Waukesha is similarly in contrast with the O'Neill as the latter type has a sandy to gravelly subsoil.

The relationship to texture is also shown quite distinctly in the case of nitrogen. The Webster silty clay loam on the uplands is richer in this constituent than the other types while the silt loams are very much better supplied than the sandy types. On the terraces the Fargo silty clay loam is much higher in nitrogen than the silt loam and loams of other series. The Waukesha silt loam is higher than the loams except for the O'Neill loam which is somewhat better supplied than the Waukesha. The differences here are not very great. In all these comparisons it is important to remember that these soils are all of different series and hence there are effects which are not due entirely to differences in texture. The characteristics which serve to differentiate the soils into series may affect the nitrogen content. Only on the bottoms is it possible to draw a comparison between the effects of the soil texture on the nitrogen content within a certain series. Here the Lamoure silty clay loam is much higher in nitrogen than the Lamoure loam. The Wabash silt loam is somewhat better supplied than the Wabash loam. These differences may be attributed in very large part to the differences in texture inasmuch as the soils are of the same series. It would seem from these few comparisons that the conclusions previously reached in this respect are very largely confirmed since fine-textured types appear to be richer in nitrogen than coarse textured soils. Thus silty clay loams are richer in nitro-

gen than silt loams, silt loams are better supplied than loams, and loams are usually higher in nitrogen than sandy types.

While these analyses show a rather considerable content of nitrogen in most of the soils of the county, this element cannot be disregarded when systems of permanent fertility are planned for the county. The supply of nitrogen must be kept up in these soils and in a few cases, as in the Dickinson fine sandy loam, it is important that some method be followed at the present time to increase the supply of nitrogen.

Farm manure is a very important nitrogenous fertilizer and if used liberally will aid materially in keeping up the nitrogen supply in the soil. Crop residues will also supply considerable nitrogen. The use of leguminous crops as green manures is, however, the most important farm practice from the standpoint of increasing nitrogen in the soil. Turning under well-inoculated legumes as green manures is the cheapest and best method of building up and maintaining the nitrogen content of the soil. These natural fertilizing materials supply considerable amounts of organic matter as well as nitrogen and hence they have a double value in keeping soils productive.

The relationship between the nitrogen content in soils and the amount of organic matter or organic carbon indicates the rapidity with which the plant food constituents in the soil are being changed into an available form. In many of the soils in O'Brien County, there are evidences that the decomposition processes are not proceding entirely satisfactorily and there is undoubtedly a very slow production of available plant food in many cases. This condition is noted particularly in the Carrington silt loam and the Webster silty clay loam on the uplands and in many of the types on the terraces and bottoms. In such cases the application of farm manure is of particularly large value inasmuch as this material provides large numbers of microorganisms which bring about a rapid decomposition of the plant food constituents in the soil and lead to a greater supply of plant food being made available to the crops.

The organic carbon content in the O'Brien County soils varies quite widely —from 26,160 pounds in the Dickinson fine sandy loam up to 134,450 pounds in the Lamoure silty clay loam. These are the same types which showed the lowest and highest content of nitrogen, respectively. In general the relationships between the various soils and their organic carbon content are very much the same as those noted in the case of nitrogen. Thus the Webster silty clay loam on the drift uplands is richer in organic matter than the Clarion, Carrington and Dickinson soils and the Clarion and Carrington types are better supplied than the Dickinson. On the terraces the Fargo soils are richer than the other terrace types, the Waukesha soils come second and these are followed by the O'Neill, the Judson and the Sioux types. On the bottoms one of the Lamoure soils is richer in organic matter than the Wabash types but the other is not so well supplied. The effect of differences in texture is important in this connection.

As was noted in the case of nitrogen, few comparisons based on textural differences can be made. The Lamoure silty clay loam is much better supplied than the loam of the same series and the Wabash silt loam is richer in organic matter than the Wabash loam. On the uplands and the terraces the soils are all of different types and hence in making comparisons in organic matter content, the effect of series characteristics must be taken into consideration, along with textural differences.

Apparently the soil characteristics which serve to distinguish series and types are very closely related to the organic carbon content, just as was noted in the case of nitrogen. Those soils which are fine in texture, dark in color, level in topography and poorly drained with heavy subsoils apparently are much higher in organic carbon as well as in nitrogen. On the other hand, coarse textured types which are light colored, rolling in topography, and have light textured subsoils are almost certain to be poorly supplied in these constituents.

Fig. 4. Rural school, O'Brien County.

While the soils of O'Brien County in general are fairly well supplied with organic matter, methods of soil treatment need to be adopted which will provide for the regular addition of fertilizing materials supplying this constituent. In one or two cases the supply of organic matter is low and in such instances large additions of materials supplying organic matter are very necessary. The liberal use of farm manure is of particularly large value to build up and maintain the supply of organic matter. The proper use of crop residues will aid in this connection and the turning under of leguminous crops as green manures is also very desirable. With the proper use of farm manure, crop residues and leguminous green manures, there is no need of the soils of this county ever becoming deficient in organic matter.

Four of the soils types in the county show inorganic carbon in the surface soils. These are the Webster silty clay loam on the drift upland, the Sioux loam, a terrace type, and the Lamoure types on the bottoms. These soils are high in content of lime, and hence show no lime requirement by the acidity test. The other soil types in the county all show an acid reaction and no inorganic carbon, hence they are generally in need of lime. In one or two cases the underlying soil layers are high in lime and in the case of the Fargo silty clay loam on the terrace, the subsurface soil is high in lime, hence this type would not need additions of lime at present.

The content of inorganic carbon in the soil is related directly to the characteristics which determine the soil series, thus it is typical of the Webster soils, the Sioux soils, the Fargo soils and the Lamoure types to show a content of inorganic carbon or lime in the subsoil. Frequently the surface soil of these types is also high in lime. Lime occurs also in many cases in the subsoils of the Clarion silt loam on the drift uplands and in the Marshall silt loam and the flat phase of the Marshall silt loam on the loessial uplands. In general, however, where the surface soil shows an acidity, lime is needed to secure the best growth of farm crops, particularly of legumes. Hence it may be said that the soils of the county, with the exception of the Webster, the Sioux, the Fargo and the Lamoure types, should be tested for acidity or lime requirement regularly and the amount of lime shown to be necessary according to the test should be applied.

The amount of lime needed by the various soils of the county which are acid

in reaction in the surface soil is indicated in the table. These figures should be considered merely to indicate roughly the needs of the soil. The lime requirement of soils varies widely even within the same type and tests of soil from a particular field are necessary if the limestone requirement is to be determined accurately.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,0O0 pounds of subsoil per acre.

It is hardly necessary to discuss the results of these analyses in detail inasmuch as the amount of plant food in the lower soil layers has very little influence upon the fertility of the soil, as indicated by the analysis of the surface layers, unless there is a very large amount of some constituent present or a striking deficiency of an element. In O'Brien County the lower soil layers are not particularly high in any plant food nor is there any large deficiency. It would seem, therefore, that the analyses of the surface soils have indicated quite accurately the plant food content of the soils as a whole and in general the crop producing power. The results of the analyses of the lower soil layers may be considered, therefore, merely to confirm the results secured in the analyses of the surface soil.

It is apparent that the phosphorus content of the soils of the county is low and additions of phosphorus fertilizers will certainly be necessary in the future. The indications are that they might prove of value in many cases at the present time. The content of organic matter and nitrogen in most of the soils is quite adequate at present but the supply must be maintained if the soils are to continue productive. This may be accomplished thru the proper use of farm manure, crop residues and leguminous green manures, the latter being especially valuable for keeping up the nitrogen content as well as the organic matter supply.

TABLE V. PLANT FOOD IN O'BRIEN COUNTY, IOWA, SOILS

Pounds Per Acre of 4 Million Pounds of Subsurface Soil (6 2/3″-20″)

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
169	Clarion silt loam.....	1,426	8,640	90,028	....	2,000
83	Carrington silt loam.....	1,480	5,480	56,680	....	2,000
107	Webster silty clay loam.....	2,342	7,320	76,055	1,880	....
175	Dickinson fine sandy loam...	1,534	2,560	36,515	....	1,000
	LOESS SOILS					
9	Marshall silt loam	2,060	7,420	84,202	....	2,500
74	Marshall silt loam (flat phase)	1,508	8,200	99,244	....	1,000
	TERRACE SOILS					
109	Fargo silty clay loam.....	2,208	6,640	72,049	7,521	....
75	Waukesha silt loam.....	2,208	6,760	78,480	....	4,000
108	O'Neill loam	2,046	3,720	44,690	....	3,000
190	Judson loam	3,150	6,120	77,935	....	2,000
76	Sioux loam	2,100	5,200	60,492	37,608	....
	SWAMP AND BOTTOMLAND SOILS					
111	Lamoure silty clay loam....	2,908	12,600	161,265	42,515	....
112	Lamoure loam	2,316	3,880	48,995	33,847	....
49	Wabash loam	2,532	9,040	108,755	....	1,000
26	Wabash silt loam.....	3,448	9,720	112,208	....	1,000

TABLE VI. PLANT FOOD IN O'BRIEN 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					
169	Clarion silt loam.....	2,625	2,880	41,076	22,689	....
83	Carrington silt loam.....	2,220	3,240	35,970	....	2,000
107	Webster silty clay loam.....	3,312	5,280	61,672	13,538	....
175	Dickinson fine sandy loam...	1,899	2,260	34,335	....	1,000
	LOESS SOILS					
9	Marshall silt loam.....	2,625	4,440	49,291	41,074	....
74	Marshall silt loam (flat phase)	1,899	4,200	77,091	58,614	....
	TERRACE SOILS					
109	Fargo silty clay loam.....	3,354	4,440	49,743	19,744	....
75	Waukesha silt loam.....	2,667	4,440	47,415	....	4,000
108	O'Neill loam	2,343	2,280	43,372	....	1,500
190	Judson loam	4,485	6,120	122,625	....	2,000
76	Sioux loam	3,312	5,520	64,129	53,591	....
	SWAMP AND BOTTOMLAND SOILS					
111	Lamoure silty clay loam.....	2,787	6,120	95,246	11,846	....
112	Lamoure loam	3,354	5,520	67,537	57,540	....
49	Wabash loam	4,281	12,480	155,472	....	1,500
26	Wabash silt loam	5,253	7,800	94,012	....	1,000

In one or two instances some lime occurs in the lower soil layers where the surface soil is acid but in general the amount present would not change the conclusions drawn regarding the needs of the surface soil. Lime does not move up in the soil to any considerable extent and the content of the lower soil layers has little effect on the requirement of the surface soil. It would seem, therefore, that on all the types in the county except the Webster, Sioux, Fargo and Lamoure soils, the surface soils may be acid and in need of lime. They should be tested for acidity or lime requirement, therefore, and the amount of lime which the test shows to be necessary should be applied if the best growth of general farm crops and particularly of legumes is to be secured.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from O'Brien County in order to secure some information regarding their fertilizer needs and regarding the value of the application of certain fertilizing materials. These tests were carried out on the Marshall silt loam and the Webster silty clay loam, two of the most extensive soil types in the county. Experiments are also included on the Marshall silt loam from Woodbury County, on the Marshall silt loam from Montgomery County, on the Webster silty clay loam from Buena Vista County and on the Carrington silt loam from Clay County. These soils are the same as those occurring in O'Brien County and the results secured may be considered, therefore, to indicate quite definitely the effects of the same fertilizer treatment on the soils of O'Brien County.

The fertilizer treatments employed were the same in all the experiments and they included the application of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. These materials all were added in the same amounts in which they are applied in the field and hence the results may serve to indicate just what the fertilizer effects may be on the farm. Manure was added at the rate of 8 tons per acre, lime was applied in amounts sufficient

TABLE VII. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, O'BRIEN COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	4.70	5.5
2	Manure	5.60	36.5
3	Manure+lime	6.20	38.8
4	Manure+lime+rock phosphate	6.15	44.8
5	Manure+lime+acid phosphate	6.40	46.4
6	Manure+lime+complete commercial fertilizer	6.80	44.2

to neutralize the acidity of the soil and add 2 tons additional, rock phosphate was applied at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in all the experiments, the clover being seeded about one month after the wheat was up.

RESULTS ON THE MARSHALL SILT LOAM

The results of the experiment on the Marshall silt loam from O'Brien County are given in table VII. The figures are the averages of the weight of the wheat grain and of the clover crop on the duplicate pots.

The application of manure brought about considerable effects on this soil both with wheat and with clover. With the latter crop there was a very large increase in the yield. The clover crop on the check pots in this series was very small. While the influence of manure on the various farm crops on this type is always large, it is undoubtedly greater in this particular case than would ordinarily be expected. The addition of lime with the manure was likewise of value on both crops. The beneficial effect of this material on clover is commonly expected but ordinarily beneficial effects on wheat are not secured from the use of lime. In many instances, however, the lime seems to benefit the grain crops in the rotation. The addition of rock phosphate with the manure and lime had no effect on the wheat but brought about a considerable increase in the clover. Acid phosphate with the manure and lime gave a distinct increase in the wheat

Fig. 5. Clover on Marshall silt loam, O'Brien County.

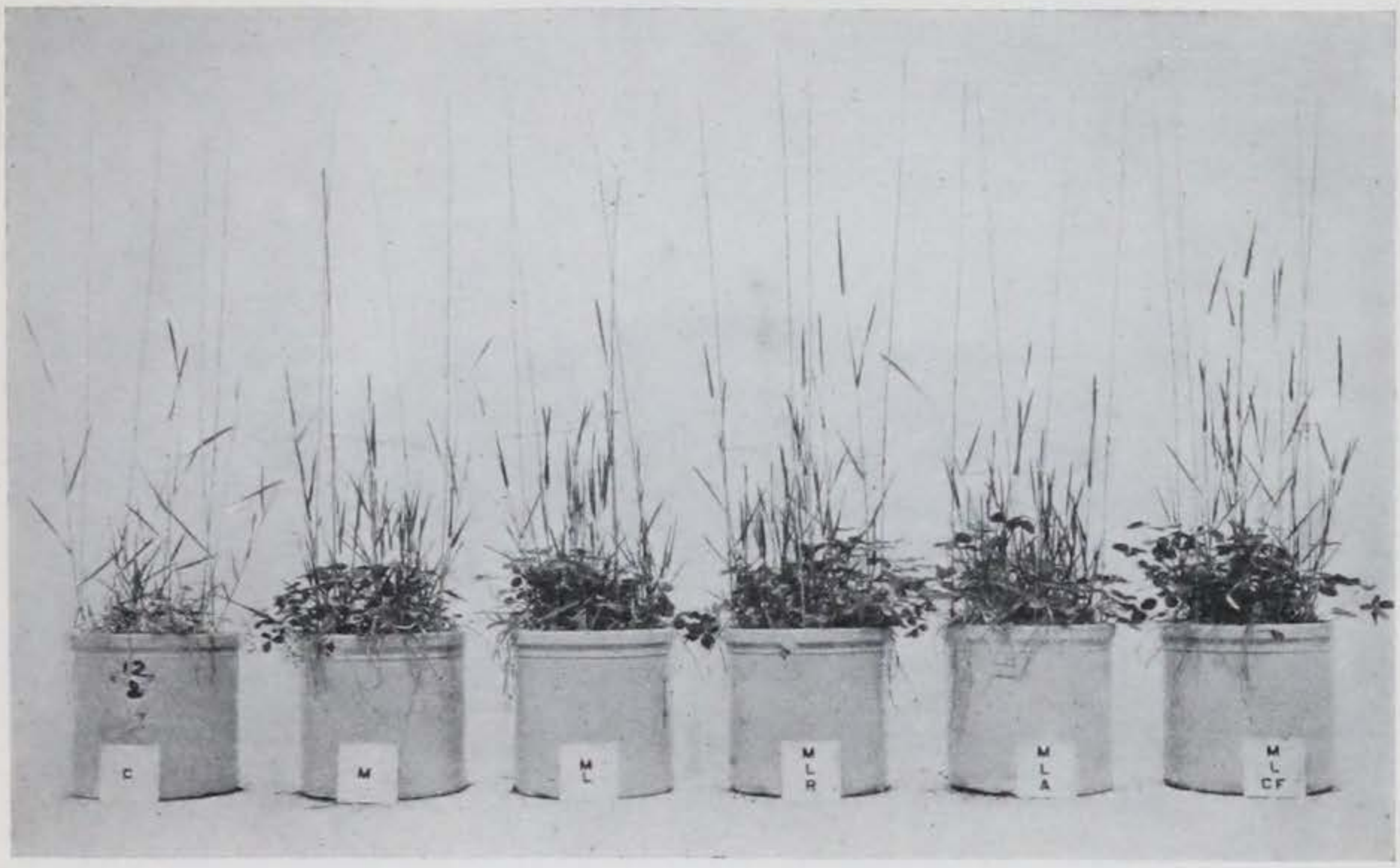


Fig. 6. Wheat and clover on Marshall silt loam, O'Brien County.

and a larger increase on the clover than was true of the rock phosphate. The complete commercial fertilizer showed up better than either of the phosphates in the case of the wheat but had lesser effect on the clover.

It would seem, therefore, from these results that this soil will respond very largely to applications of manure, lime and a phosphorus fertilizer. Particularly beneficial effects were noted upon the application of manure. Lime in addition brought about appreciable increases in crop yields and the addition of a phosphate fertilizer proved of value. Acid phosphate seemed to be preferable to rock phosphate for both the wheat and the clover in this test, but the results are not very widely different, hence definite conclusions regarding the merits of these two fertilizers can hardly be drawn from the data available. The complete commercial fertilizer showed up better on the wheat than did the phosphates but had a smaller effect on the clover. It would not seem, therefore, that this material would be of as large value as the phosphate carriers.

RESULTS ON WEBSTER SILTY CLAY LOAM

The results secured on the Webster silty clay loam from O'Brien County are given in table VIII. The beneficial effect of manure on this soil is very definitely shown by the data given in the table. There was a very large increase in the yield of wheat and the yield of clover was increased enormously. In fact in this experiment the manure brought about a very much larger increase in the clover crop than would ordinarily be expected. Apparently the yield on the check plot was abnormally low in this particular case. Lime in addition to manure increased the yield of wheat and brought about a pronounced increase in the case of the clover. The particular sample of Webster silty clay loam used in the greenhouse experiments was acid in reaction and hence the effect of lime was noted in these results. In many cases this type is basic in reaction and does not need an addition of lime.

The use of rock phosphate with manure and lime increased the wheat yield to some extent and brought about a very appreciable increase on the clover. Acid phosphate showed up very much better on the wheat than the rock phosphate

Fig. 7. Clover on Webster silty clay loam, O'Brien County.

but had about the same effect on the clover. The complete commercial fertilizer had less influence on the wheat than the phosphates and less also on the clover.

On this soil, it would seem that additions of manure will be of considerable value even tho the type is high in organic matter and black in color. Apparently the addition of manure stimulates the production of available plant food to an extent which increases the crop yields. When the type is acid in reaction, additions of lime are certainly very desirable, and increases in the yield of both grains and leguminous crops may be secured. The use of a phosphate fertilizer seems to be of considerable value on the soil. Whether acid phosphate or rock phosphate should be used cannot be determined definitely from the data given,

Fig. 8. Wheat and clover on Webster silty clay loam, O'Brien County.

TABLE VIII. GREENHOUSE EXPERIMENT, WEBSTER SILTY CLAY LOAM, O'BRIEN COUNTY

Pot No.	Treatment	Weight of wheat grains in grams	Weight of clover in grams
1	Check	7.9	6.6
2	Manure	10.2	24.9
3	Manure+lime	11.8	30.2
4	Manure+lime+rock phosphate	12.6	33.2
5	Manure+lime+acid phosphate	13.8	33.0
6	Manure+lime+complete commercial fertilizer	12.1	31.7

however, inasmuch as the differences are not definite enough. It would seem that acid phosphate is a little better for use in the case of a crop like wheat but, with other crops, rock phosphate might prove quite as valuable. The complete commercial fertilizer showed up in a smaller way than did the phosphate fertilizer hence this material would not seem as desirable for use as the phosphorus carriers.

RESULTS ON MARSHALL SILT LOAM FROM WOODBURY COUNTY

The results secured on the Marshall silt loam from Woodbury County are given in table IX. Manure brought about a distinct increase in the yields of wheat and clover on this soil. Lime with manure gave a pronounced increase in the yield of wheat but showed no effect on the clover. This is contrary to the usual results, as lime ordinarily has a considerable effect on legume crops grown on the Marshall silt loam. This is especially true if the type is distinctly acid in reaction. Apparently the particular sample used in this experiment was only slightly acid in reaction and the effects of the lime was not evidenced.

The addition of rock phosphate or acid phosphate with the manure and lime brought about distinct increases in the yield of wheat and the acid phosphate showed a very pronounced gain in the yield of clover. Rock phosphate had little effect on the latter crop but showed up to a small extent on the wheat, less, however, than was true of the acid phosphate. The complete commercial fertilizer showed up better than the phosphates on the wheat but had a smaller effect than the acid phosphate in the case of clover.

The results of this experiment confirm those secured on the same type from O'Brien County. They indicate the large value of the application of manure, lime and a phosphate fertilizer on this soil. Manure has a very pronounced effect on the growth of general farm crops on this type. When the type is acid in reaction, additions of lime are very desirable and increases in crop yields are generally quite pronounced. Ordinarily leguminous crops are expected to show the effect of lime in a larger way than is true of non-legumes, but in some cases non-leguminous crops may be very strikingly benefited. Phosphorus fertilizers are of large value and it would seem that acid phosphate is somewhat preferable to rock phosphate. However, the data from these experiments should not be considered conclusive and tests of phosphorus fertilizers on individual

TABLE IX. GREENHOUSE EXPERIMENT. MARSHALL SILT LOAM, WOODBURY COUNTY

Pot No.	Treatment	Wt. wheat in grams	Wt. clover in grams
1	Check	7.051	35.0
2	Manure	7.850	39.0
3	Manure+lime	8.946	35.0
4	Manure+lime+rock phosphate	9.023	39.0
5	Manure+lime+acid phosphate	9.247	48.5
6	Manure+lime+complete commercial fertilizer	10.216	45.0

Fig. 9. Clover pot culture on Marshall silt loam, Montgomery County, indicated the value of manure.

farms are very desirable. The complete commercial fertilizer can hardly be recommended for use over acid phosphate inasmuch as it does not always give larger returns. The crop increases from this material must be sufficiently greater to warrant the additional cost before it can be recommended for general use.

RESULTS ON MARSHALL SILT LOAM FROM MONTGOMERY COUNTY

Results secured on the Marshall silt loam from Montgomery County in 1919 are given in table X. In this experiment the yields on the pots receiving the complete commercial fertilizer are not given as the crops were injured. Again the beneficial effect of manure on the wheat and clover in the test is evidenced by the data. A very large effect was noted on the clover. Lime with the manure increased the yield of the wheat but showed very little effect on the clover, due undoubtedly to the fact that the particular sample was only slightly acid in reaction and the need of lime was not very evident. Rock phosphate showed up a little better on the wheat but the acid phosphate was very much better in the case of the clover.

These results would serve to confirm the data secured in the experiments previously discussed as they indicate very large value from the application of manure, lime and a phosphorus fertilizer to this type. Manure seems to be of particularly large value as has been noted in the other experiments. Lime may prove of value when the type is acid. The effect may not be large when there is only a slight acidity present, but in many cases considerable beneficial effects from the addition of lime to the type when it is acid have been noted. The use of a phosphate fertilizer is certainly very desirable as large increases in crop yields are secured from the use of one of the two important phosphorus carriers. Whether rock phosphate or acid phosphate should be used cannot be definitely stated as in some cases the rock phosphate seems to be quite as satisfactory while in other instances acid phosphate is much more effective.

TABLE X. GREENHOUSE EXPERIMENT—MARSHALL SILT LOAM, MONTGOMERY COUNTY, 1919

Pot No.	Treatment	Weight of wheat in grams	Weight of clover in grams
1	Check	15.25	83.9
2	Manure	15.75	90.7
3	Manure+lime	16.00	88.4
4	Manure+lime+rock phosphate	18.50	97.5
5	Manure+lime+acid phosphate	17.00	104.3

RESULTS ON THE WEBSTER SILTY CLAY LOAM FROM BUENA VISTA COUNTY

The results secured on the Webster silty clay loam from Buena Vista County are given in table XI. The beneficial effect of manure on the Webster silty clay loam is shown very definitely in this experiment. Yields of wheat were increased considerably and a pronounced effect on the clover was evidenced. The addition of lime with the manure brought about a further increase in the yields of both crops. The effect was particularly evidenced in the case of the clover. This sample of Webster silty clay loam was acid in reaction in the surface soil and the addition of lime brought about a beneficial effect. The application of rock phosphate had no effect on the wheat but showed a beneficial effect on the clover. Acid phosphate brought about a considerable increase in the yield of wheat and had a very pronounced influence on the clover. The complete commercial fertilizer had less effect than the acid phosphate on the wheat but was slightly better on the clover.

Results secured in this test confirm those obtained on the same soil type from O'Brien county, indicating the large value from the application of manure, lime and a phosphorus fertilizer to this particular soil. If the type is not acid lime should not be used but when it is acid, applications of lime are necessary. The application of manure is of large value in spite of the fact that the type is high in organic matter and black in color, probably due to the introduction of bacteria and other micro-organisms which bring about an increase in the production of available plant food.

The use of a phosphorus fertilizer is of very considerable value on this soil and it would seem that acid phosphate would be preferable for use. However, the tests are not very definite and in many cases perhaps rock phosphate might prove quite as useful. The complete commercial fertilizer seems to be less effective than the phosphorus carriers in this particular experiment but tests on individual farms may be carried out if desired.

RESULTS ON THE CARRINGTON SILT LOAM FROM CLAY COUNTY

The results secured on the Carrington silt loam from Clay County are given in table XII. The beneficial effects of applications of manure to this soil are very definitely shown by the increased yields of wheat and clover, obtained in this experiment. A very large increase in wheat was secured and there was a pronounced gain in the clover crop. Lime with manure had little effect on the wheat but brought about a slight increase in the clover. Rock phosphate with the manure and lime showed no effect on the wheat and little or no effect on the clover. The acid phosphate with the manure and lime gave a slight increase on the wheat and brought about a very large gain in the clover. The complete commercial fertilizer with the manure and lime gave an increase in the wheat yields and an increase also in the clover. In fact the complete commercial fertilizer showed a larger effect on both the wheat and clover than did the acid phosphate.

TABLE XI. GREENHOUSE EXPERIMENT. WEBSTER SILTY CLAY LOAM—BUENA VISTA COUNTY

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

TABLE XII. GREENHOUSE EXPERIMENTS. CARRINGTON SILT LOAM, CLAY COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	19.54	25.5
2	Manure	23.40	41.5
3	Manure+lime	23.55	42.5
4	Manure+lime+rock phosphate	23.16	40.5
5	Manure+lime+acid phosphate	23.60	52.0
6	Manure+lime+complete commercial fertilizer	24.27	56.5

On this soil type applications of manure are undoubtedly of very large value, as the yields in this experiment have indicated large effects on wheat and clover and much practical experience has shown similar large effects on general farm crops. Lime with manure is very desirable for use as the soil is acid in reaction and general farm crops as well as legumes may show a response to additions of lime. The use of a phosphate fertilizer seems very desirable. Acid phosphate showed up better than rock phosphate in this particular test but definite conclusions should not be drawn from a single experiment. The complete commercial fertilizer seemed a little better than acid phosphate in this experiment but the difference was not great enough to warrant the greater cost of the complete fertilizer and it is probably true that in general acid phosphate would prove quite as beneficial on crop yields and it is less expensive.

FIELD EXPERIMENTS

One field experiment has been laid out in O'Brien County but the experiment has not been under way long enough for the results to be of significance. A number of experiments are located, however, in adjacent counties on soil types which occur extensively in O'Brien County and some of these field experiments will be described here inasmuch as they indicate quite definitely the results which may be secured on the same soils in this county. Experiments are included here on the Marshall silt loam on the Avoca field in Pottawattamie County, on the Waukesha silt loam on the Clarinda field in Page County, on the Webster silty clay loam on the Everly field in Clay County, on the Webster silty clay loam on the Newell field in Buena Vista County, on the Carrington silt loam on the Osage field in Mitchell County, on the Marshall silt loam on the Red Oak field in Montgomery County, on the Webster silty clay loam on the Storm Lake field in Buena Vista County and on the Marshall silt loam on the Villisca field in Montgomery County. The average results secured on the Marshall silt loam on all the fields on that type in the state are also included.

These field experiments are all planned to determine the value of various fertilizing materials when applied to the soil and the experiments are laid out on land which is representative of the particular soil types. The fields all include 13 plots, each 155′ 7″ by 28′, or one-tenth of an acre in size. They are permanently located by the installation of corner stakes and all precautions are taken in the application of fertilizers and in the harvesting of the crops to insure accurate results.

The fields include tests under the livestock system of farming and under the grain system. In the former, manure is applied while in the latter crop residues are employed. The other fertilizing materials tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure is applied at the rate of 8 tons per acre once in a four-year rotation. The crop residues treatment consists of the plowing under of the cornstalks which have been cut with a disk or stalk-cutter, the turning under of the straw from the small grain, and the plowing under of at least the second crop of clover. Some-

times the first crop of clover is cut and allowed to remain on the land to be plowed under with the second crop. Lime is applied in sufficient amount to neutralize the acidity of the soil and supply 2 tons additional. Rock phosphate is added at the rate of 2,000 pounds per acre once in a four-year rotation. Acid phosphate is employed at the rate of 200 pounds per acre annually. Until 1923 the old standard 2-8-2 complete commercial fertilizer was used at the rate of 300 pounds per acre annually. The new standard 2-12-2 brand is now being applied at the rate of 267 pounds per acre, thus applying the same amount of phosphorus as that contained in the 200 pounds of acid phosphate.

THE AVOCA FIELD

The results secured on the Marshall silt loam on the Avoca field in Pottawattamie County are given in table XIII. The application of manure to this soil brought about an increase in crop yields in most cases. The influence of the manure was particularly evidenced on the clover in 1921 and on the biennial sweet clover in 1924. The oats in 1920 and again in 1923 were very largely increased by the addition of the manure. Lime was not applied until the fall of 1920. The application of lime with the manure increased the crop yields in most cases, the effect being particularly evidenced on the biennial sweet clover in 1924. Increases were also secured on the corn in 1922 but no effect was evidenced on the clover in 1921 and the oats in 1923.

The addition of rock phosphate or acid phosphate with manure and lime brought about pronounced increases in crop yields in some cases. The corn in 1919 showed gains from the use of both phosphates, the acid phosphate showing up somewhat better than the rock phosphate. In 1922 similar increases were secured on the corn and again, in 1923, the oats were increased in a large way by the application of the phosphates. The clover, both the red clover and the biennial sweet clover, showed little effect from the phosphate addition. The application of a complete commercial fertilizer with manure and lime had about

TABLE XIII. FIELD EXPERIMENT—MARSHALL SILT LOAM—POTTAWATTAMIE COUNTY. AVOCA FIELD.

Plot No.	Treatment	1919[1] Corn bu. per A.	1920[2] Oats bu. per A.	1921[3] Clover tons per A.	1922[4] Corn bu. per A.	1923 Oats bu. per A.	1924 Biennial Sweet Clover tons per A.
1	Check	72.9	62.2	2.0	58.1	48.7	0.36
2	Manure	72.1	69.0	2.7	53.6	56.7	0.63
3	Manure+lime	74.0	72.3	2.6	53.9	53.2	1.82
4	Manure+lime+rock phosphate	77.8	58.8	2.7	55.5	60.0	1.52
5	Manure+lime+acid phosphate	79.3	69.0	2.5	56.5	60.0	1.68
6	Manure+lime+complete commercial fertilizer	77.5	61.2	2.8	57.5	66.8	1.92
7	Check	71.5	56.8	2.0	44.8	47.6	0.85
8	Crop residues	78.9	63.9	2.0	44.8	49.8	0.90
9	Crop residues+lime	80.7	68.1	2.1	50.0	56.7	1.92
10	Crop residues+lime+rock phosphate	78.5	68.6	2.8	54.8	59.0	1.83
11	Crop residues+lime+acid phosphate	81.1	75.1	2.2	54.1	64.5	1.50
12	Crop residues+lime+complete commercial fertilizer	80.4	68.6	2.9	52.0	52.1	1.44
13	Check	80.0	68.6	2.2	46.3	50.9	1.12

[1]Field slopes toward Plot 13.
[2]Not limed until October 1, 1920. Three tons per acre.
[3]Field pastured until June 1.
[4]Corn injured by hail in August and by rainy spring.

the same effect as the phosphates in the case of the corn crop but was very much more beneficial on the oats and the clover crop, showing up particularly well on the biennial sweet clover in 1924.

The crop residues treatment had little effect on the crop yields except in one or two cases. The addition of lime with the crop residues brought about increased crop yields in several instances. The effect of the lime was particularly evidenced again on the biennial sweet clover in 1924, when a large increase was brought about. The corn in 1922 and the oats in 1923 were both increased, however, by the addition of lime.

The application of rock phosphate or acid phosphate with the crop residues and lime had beneficial effects on many of the crops grown. The acid phosphate showed up particularly well on the oats in 1920 and again on the same crop in 1923. The rock phosphate showed up a little better than the acid phosphate on the clover in 1921 and also on the corn in 1922. In general, however, the differences were not very definite. The complete commercial fertilizer had less effect than the acid phosphate on the oats in 1923 and on the oats in 1920 but it showed up better than the acid phosphate on the clover in 1921. In other cases the complete fertilizer was very much the same in effect as the acid phosphate.

In general it appears from the results that the Marshall silt loam will respond in a very large way to applications of farm manure and liberal amounts of this fertilizing material are very desirable for use. When the type is acid, as is usually the case, additions of lime are very necessary in order to secure the best crops of legumes and in many cases considerable increases are secured in the yields of general farm crops. The application of a phosphate fertilizer to this type will undoubtedly prove of large value. Increases in crop yields have been secured from the use of acid phosphate and from the application of rock phosphate. In many cases acid phosphate seems to be somewhat preferable but the differences are not sufficiently definite to warrant a recommendation for the use of acid phosphate on the type in all cases. Farmers may test the two materials on their own soils and determine for their particular conditions which should be employed. The complete commercial fertilizer shows up about as well as the acid phosphate or even a little better in some cases. The differences, however, are not sufficiently greater to warrant the use of the more expensive complete fertilizer.

THE CLARINDA FIELD

The results secured on the Waukesha silt loam on the Clarinda field in Page County are given in table XIV. The beneficial effects of the manure were evidenced on the clover in 1917 and on the corn in 1922 and 1923, in particularly large increases. Beneficial effects were also shown on other crops grown on this field. Lime with manure proved of value on this type, the beneficial effects being particularly noticeable on the clover in 1917. Large increases in yields were also secured from the use of lime on the oats in various seasons and on some of the corn crops. Ordinarily lime would not be expected to bring about large effects on the corn and small grain crops but the beneficial effect would be evidenced particularly on the legume crop grown in the rotation. It would seem, however, that the lime is of value on this soil because of increases brought about in all general farm crops.

Applications of rock phosphate or acid phosphate with the manure and lime brought about increases in crop yields in most cases. The beneficial effect of both the phosphates was evidenced particularly on the clover in 1917. The acid phosphate brought about a very large increase in the yield of clover, showing up much better than the rock phosphate. Considerable increases in crops were also secured in the case of corn in 1916 and in 1919, the acid phosphate again show-

TABLE XIV. FIELD EXPERIMENT—WAUKESHA SILT LOAM—PAGE COUNTY.
CLARINDA FIELD—SERIES 100

Plot No.	Treatment	1915[1] Corn bu. per A.	1916 Oats bu. per A.	1917 Clover tons per A.	1918[2] Corn bu. per A.	1919[3] Corn bu. per A.	1920[4] Oats bu. per A.	1921 Soybeans bu. per A.	1922 Corn bu. per A.	1923[5] Corn bu. per A.	1924 Oats bu. per A.
1	Check	51.2	61.1	1.19	....	55.1	51.0	23.5	79.4	65.9	55.6
2	Manure	49.9	54.4	1.36	....	58.7	52.3	25.3	87.4	73.7	53.4
3	Manure+lime	50.6	63.3	1.56	....	62.6	61.8	25.2	89.6	73.6	61.3
4	Manure+lime+ rock phosphate.	48.2	50.0	2.89	....	69.3	63.6	24.2	87.9	82.1	53.7
5	Manure+lime+ acid phosphate..	54.8	52.2	3.40	....	70.9	60.4	24.3	88.3	78.0	56.7
6	Manure+lime+ complete commercial fertilizer	49.7	50.0	2.55	....	59.7	73.5	23.3	90.8	76.7	66.0
7	Check	48.0	47.7	1.36	....	56.3	41.8	24.0	82.4	64.6	46.5
8	Crop residues	45.2	41.1	1.53	....	56.5	55.7	23.0	71.8	53.8	61.4
9	Cros residues+ lime	51.4	43.3	2.21	....	58.2	58.7	25.8	81.2	48.6	49.0
10	Crop residues+ lime+rock phosphate	51.6	47.7	2.71	....	66.7	61.1	25.8	85.2	54.5	52.7
11	Cros residues+ lime+acid phosphate	53.4	54.4	2.89	....	69.8	60.4	24.8	87.5	57.2	54.1
12	Cros residues+ lime+complete commercial fertilizer	50.3	47.7	2.72	....	65.3	62.4	24.8	90.6	70.1	58.8
13	Check	50.5	47.7	1.36	....	57.2	42.5	22.5	88.7	71.8	43.9

[1]Wet season.
[2]Hot wind July 18, ruined crop.
[3]Dry season reduced yields.
[4]Plot 13 low poorly drained.
[5]Wet weather necessitated replanting.

ing up much better than the rock phosphate. The complete commercial fertilizers with the manure and lime had no greater effect than the acid phosphate except on the oats in 1920, on the corn in 1922 and on the oats in 1924. In most cases the acid phosphate gave even larger results than the complete commercial fertilizer.

The use of crop residues had little effect on any of the crops grown, except in a few cases. Lime, with the crop residues, brought about pronounced increases in crop yields in practically all instances. The beneficial effects of the lime were evidenced particularly on the clover in 1917. The soybeans in 1921 were also increased. A large effect was shown on the corn crop in some seasons, notably in 1915 and in 1922. Again the application of lime increased considerably the yields of general farm crops as well as of the legumes.

The application of rock phosphate or acid phosphate with the crop residues and lime showed beneficial effects on practically all of the crops grown. The increases were noted particularly on the clover in 1917, on the oats in 1916, on the corn in 1919 and on the corn in 1922. In general the acid phosphate gave a greater effect than the rock phosphate, in some cases showing very much larger increases in yields than those brought about by the rock phosphate. The complete commercial fertilizer had less effect than the acid phosphate in several cases. On the oats in 1920, the corn in 1922, the corn in 1923, and the oats in 1924, however, increases for the complete commercial fertilizer were greater than those brought about by the acid phosphate.

The results on the Waukesha silt loam indicate that there may be large beneficial effects secured from the application of manure, lime and a phosphate fertilizer. The addition of farm manure brings about large increases in the yields of all farm crops and liberal amounts of this material should be applied to the type. The application of lime is very desirable, particularly to bring about the profitable growth of leguminous crops. Very large increases in the yields of general farm crops may, however, be secured from the application of lime. The use of a phosphate fertilizer would seem to be profitable on this soil and, in many cases, very large increases in crop yields have been secured from the use of acid phosphate. In other instances, rock phosphate has proven almost as satisfactory for use and hence definite recommendations regarding the use of one or the other of these fertilizing materials cannot at present be made. Tests on individual farms of both acid phosphate and rock phosphate are very desirable. It would not seem from the data available that a complete commercial fertilizer will not prove as desirable for use as the application of acid phosphate because the complete fertilizer will not bring about any sufficiently larger increases in crop yields to warrant the greater expense of the application.

THE EVERLY FIELD—SERIES II

The results secured on the Lamoure silty clay loam on the Everly field, Series II, in Clay County, are given in table XV. The beneficial effects of manure on this type is shown by the data given in the table. A very large increase in crop yield was secured with the oats in 1922 and the corn in 1924. The clover in 1923 also showed a pronounced benefit from the application. Even tho this type is high in organic matter and black in color, the application of manure seems to be of very large value, probably due to the stimulation in the production of available plant food. This soil was basic and no lime was applied. The addition of rock phosphate or acid phosphate with the manure brought about beneficial effects on crop yields in many cases. The acid phosphate showed up better than the rock phosphate on the clover in 1919 and also on the oats in 1922. The rock phosphate seemed a little better on the corn in 1920 and again in 1921. The complete commercial fertilizer with the manure was not superior to the acid phosphate in any case and in fact in some instances showed less effect than the rock phosphate.

The crop residues showed some effect on the crop yields in the various seasons in a few cases but the differences were not very large in any instance. The use of rock phosphate or acid phosphate with the crop residues brought about pronounced increases in crop yields in several seasons. The beneficial effect was particularly evidenced on the corn in 1920. The acid phosphate showed up better than the rock phosphate in most cases, bringing about a considerable increase in the yield of the clover in 1923 while the rock phosphate had little or no effect. Again on the oats, in 1922, the acid phosphate brought about a pronounced increase in yield while the rock phosphate had a much smaller effect. The complete commercial fertilizer had a larger effect on the clover in 1919, on the corn in 1921, on the oats in 1922 and on the clover in 1923 than did the acid phosphate. In some of these cases, however, the differences were not very large.

It would seem from this data that altho the Lamoure silty clay loam is high in organic matter and black in color, applications of farm manure in small amounts may be very desirable to increase crop yields. It should be emphasized that manure should not be applied in large amounts to this type and it should not be used just preceding the small grain crop in the rotation because of the danger of causing the crop to lodge. Small amounts, however, applied at other places in the rotation, stimulate bacterial activities and speed the production of available plant food the effect of which is to cause considerable increases in crop yields.

TABLE XV. FIELD EXPERIMENT—LAMOURE SILTY CLAY LOAM—CLAY COUNTY. EVERLY FIELD—SERIES II.

Plot No.	Treatment	1919[1] Clover tons per A.	1920[2] Corn bu. per A.	1921 Corn bu per A.	1922 Oats bu. per A.	1923[3] Clover tons per A.	1924 Corn bu. per A.
1	Check	1.45	74.6	65.8	35.6	0.57	31.8
2	Manure	1.45	....	75.3	54.1	0.71	58.2
3	Manure	1.60	83.2	75.8	70.4	1.83	69.4
4	Manure+rock phosphate	1.67	83.2	70.0	64.1	1.25	61.7
5	Manure+acid phosphate	2.03	80.8	68.1	70.2	1.75	67.2
6	Manure+complete commercial fertilizer	1.79	80.8	63.2	68.4	1.26	60.8
7	Check	1.68	66.9	54.5	58.3	0.77	43.2
8	Crop residues	1.56	....	54.7	52.8	0.87	39.6
9	Crop residues	1.56	70.4	61.9	61.1	1.47	56.5
10	Crop residues+rock phosphate	1.68	73.6	60.4	57.7	1.14	61.2
11	Crop residues+acid phosphate	1.56	83.4	60.8	62.8	1.59	57.7
12	Crop residues+complete comercial fertilizer	2.03	77.8	64.7	78.4	1.73	56.4
13	Check	1.68	61.2	54.0	48.5	0.83	35.7

[1]Clover killed out in spots.
[2]Soil basic and no lime applied. Corn on plots 2 and 8 not husked.
[3]First cutting only.

The use of a phosphate fertilizer may be very profitable on this type in many cases. In general acid phosphate seems to show up a little better than rock phosphate but the differences are not very definite and conclusions regarding the relative merits of these two fertilizers should be based on tests carried out on individual farms. The complete commercial fertilizer is no more effective than acid phosphate in many cases. In some years larger increases in crop yields were secured from the use of the complete fertilizer but in general the differences were not sufficient to warrant the greater cost of the complete fertilizer over the acid phosphate.

THE NEWELL FIELD

The results secured on the Newell field on the Webster silty clay loam in Buena Vista County are given in table XVI. The application of manure to this type brought about a beneficial effect on the crops grown in many seasons. In fact rather definite increases were secured in all cases. The corn in 1919, the oats in 1920 and the corn in 1923, showed particular evidence of value from the use of manure. While this type is high in organic matter and black in color, applications of manure apparently are of value in stimulating the production of available plant food. Limestone was applied to this field in the fall of 1920. In the years succeeding the application, there were slight beneficial effects from the use of lime, particularly on the clover in 1921 and on the corn in 1923. When this type is acid in reaction lime must be added for the best crop growth.

The application of rock phosphate or acid phosphate with manure and lime brought about very pronounced increases in crop yields in all seasons. The acid phosphate showed up better than the rock phosphate in many cases but not in all instances. The rock phosphate gave slightly larger effects than the acid phosphate in the case of the corn in 1918 and again on the corn in 1923, but in all other cases the acid phosphate proved preferable. The effect of the acid phosphate was evidenced particularly on the clover in 1921, on the oats in 1920 and on the corn in 1923. The complete commercial fertilizer with the manure

and lime showed up somewhat better than the acid phosphate in several cases, notably on the corn in 1919, on the corn in 1923, and on the oats in 1924.

The beneficial effects of the crop residues treatment were evident in the case of one or two crops grown on this field but in general very slight beneficial effects were exerted by the use of the crop residues. The addition of lime with the crop residues showed slight effect on the crops grown succeeding the application, being evidenced particularly on the corn in 1923 and the oats in 1924. The use of rock phosphate or acid phosphate with the crop residues and lime showed beneficial effects in many cases. Increases in crop yields were particularly noticeable on the clover in 1921, on the oats in 1920, and on the corn in 1923. The acid phosphate usually showed up better than the rock phosphate. This was particularly true in the case of the oats in 1920 where the acid phosphate showed a considerable gain in the crop yields while the rock phosphate showed practically no effect. Clover in 1921, was increased very much more by the acid phosphate than by the rock phosphate. The complete commercial fertilizer had no greater effect than the acid phosphate except in one or two cases where the differences were very slight.

These results show that the Webster silty clay loam will respond profitably to applications of farm manure, lime and a phosphate fertilizer. The use of a small amount of farm manure on this type is of large value in increasing the yields of general farm crops. However, farm manure should not be applied to this type just preceding the small grain crop of the rotation, owing to the danger of causing the crop to lodge. Small amounts, however, applied at other points in the rotation will prove very beneficial. When the type is acid, additions of lime should be made to the soil to bring about the best growth of general farm crops. Beneficial effects will be noted particularly on the legume of the rotation. The addition of a phosphate fertilizer will undoubtedly prove

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

Plot No.	Treatment	1918 Corn bu. per A.	1919 Corn bu. per A.	1920[1] Oats bu. per A.	1921[2] Clover tons per A.	1922[3] Corn bu. per A.	1923 Corn bu. per A.	1924[4] Oats bu. per A.
1	Check	69.0	44.8	56.7	0.52	68.7	59.2	....
2	Manure	70.9	49.1	64.1	0.60	70.5	65.6	....
3	Manure+lime	71.4	54.4	63.5	0.70	69.9	68.3	59.8
4	Manure+lime+rock phosphate	74.1	61.4	69.7	0.70	74.1	69.3	63.5
5	Manure+lime+acid phosphate	66.9	65.1	76.3	1.12	80.0	63.4	65.5
6	Manure+lime+complete commercial fertilizer	66.4	70.9	68.9	1.20	74.4	67.7	72.2
7	Check	60.9	62.4	59.4	0.57	66.9	55.0	62.3
8	Crop residues	62.9	56.1	59.4	0.50	63.6	56.4	66.5
9	Crop residues+lime .	64.6	59.2	61.4	0.42	64.2	59.5	71.8
10	Crop residues+lime+rock phosphate ...	63.4	60.8	56.7	0.52	67.3	65.9	66.9
11	Crop residues+lime+acid phosphate ...	62.4	68.5	72.0	0.90	67.3	64.1	69.3
12	Crop residues+lime+complete commercial fertilizer	61.3	65.3	71.3	0.92	67.0	65.8	....
13	Check	59.4	65.3	60.1	0.57	66.2	60.9	....

[1]Limestone applied October 11, 1920, 3½ tons. Oats down.
[2]Second cutting only.
[3]Some plots down.
[4]Oats harvested before field man arrived on Plots 1, 2, 13, 14.

profitable on this soil. Whether acid phosphate or rock phosphate should be used cannot be definitely determined from the data given, inasmuch as the acid phosphate sometimes proves of greater value while in other cases the rock phosphate seems preferable. Tests on individual farms of these two materials are very desirable. The use of a complete commercial fertilizer does not seem to be any more effective than the use of acid phosphate, hence complete fertilizers cannot be recommended for general use on this type. They certainly should not be employed until tests have been carried out in comparison with acid phosphate.

THE OSAGE FIELD

The results secured on the Carrington silt loam on the Osage field, Series I, in Mitchell County are given in table XVII. The very large beneficial effects of manure on this type are evidenced by the data given in the table. Large increases in crop yields were secured in practically all cases, the greatest effect being evidenced from the use of manure on the oats in 1920, on the clover in 1921, and on the corn in 1922. Considerable increases were also secured on the corn in 1918, in 1919, and in 1923. Apparently this soil will respond in a very large way to application of farm manure. The application of lime along with manure proved of value on many of the crops grown. The increase was particularly noted in the case of the clover. Considerable gains were also evidenced, however, on the corn in 1918 and in 1923 and on the oats in 1924.

The use of rock phosphate or acid phosphate with the manure and lime proved of value on this soil in practically all seasons. Particularly large beneficial effects from the use of one or the other of these phosphorus carriers was evidenced on the corn in 1919, on the corn in 1922, and on the oats in 1924. The acid phosphate gave larger returns on the corn in 1919, on the corn in 1922, and very much larger effects on the oats in 1924. In other cases, the rock phosphate seemed to be quite as effective as the acid phosphate. The complete commercial fertilizer with manure and lime increased the yields more than the acid phosphate in one or two cases, particularly on the oats in 1920 and on the same crop in 1924. In other cases the complete commercial fertilizer, however, did not seem to be any more effective than acid phosphate.

The application of crop residues to this soil had little effect on the crop yields except in one or two cases. The use of lime with the crop residues brought about large increases in crop yields in several instances, particularly on the corn in 1919, in 1922, in 1923 and the oats in 1924. The beneficial effects of the lime were not apparent in this particular case on the clover grown on this soil but this is contrary to the usual experience as lime ordinarily shows a particularly large effect on the legume grown in the rotation.

The use of rock phosphate or acid phosphate with the crop residues and lime proved of large value on this type. In several cases the acid phosphate seemed to give better results than the rock phosphate but not in all instances and in one or two cases the rock phosphate showed up better than the acid phosphate. The complete commercial fertilizer with the crop residues and lime gave somewhat better results than the acid phosphate in practically all cases. In one or two instances very much larger increases in crop yields were secured.

The Carrington silt loam will evidently respond in a very large way to applications of farm manure, lime and a phosphate fertilizer. The beneficial effect of manure is very largely evidenced on all general farm crops grown on this soil and liberal amounts of farm manure should certainly be applied in order to insure the best crop production on this type. The type is acid in reaction and additions of lime have very large effects not only on the legume crop grown in the rotation but also on the other general farm crops. Ordinarily the legume crop shows the greater effect from the lime but in many cases corn and oats also are very largely increased by the use of the lime. The application

of a phosphate fertilizer seems to be of large value on this soil. In many cases acid phosphate gives larger effects than the rock phosphate but in some instances rock phosphate is quite as beneficial and may indeed be somewhat larger in effect in some cases. Definite conclusions regarding the relative merits of the two phosphate carriers cannot be drawn at present and it is recommended that tests of the two materials be carried out on individual farms. While the complete commercial fertilizer showed up somewhat better than acid phosphate in some cases on this soil, the differences were not ordinarily sufficiently large to warrant the greater cost of the complete fertilizer and it would seem that in general acid phosphate would be more profitable for use on this soil.

THE RED OAK FIELD

The results secured on the Marshall silt loam on the Red Oak field in Montgomery County, are given in table XVIII. The addition of manure to the Marshall silt loam always brings about large increases in crop yields. The data given in the table bear out this statement. Particularly large effects were noted on the wheat grown in 1918 and on the oats in 1921. The use of lime was very effective in some cases. The lime was applied to this field in the spring of 1919 and in the years succeeding the application, increases in crop yields were secured in every case. The beneficial effect was evidenced on the corn, oats and wheat as well as on the legume crop.

The use of rock phosphate or acid phosphate with the manure and lime proved of value in most instances on this soil. Very large increases were secured on the winter wheat in 1922. In some cases the acid phosphate seemed to give somewhat larger effects than the rock phosphate but in some years the reverse was true. The complete commercial fertilizer was not any more effective than the acid phosphate in most instances. In one or two cases it gave slightly larger effects but in general the differences were too small to be significant.

The application of crop residues to this soil had very little effect on the crop

TABLE XVII. FIELD EXPERIMENT—CARRINGTON SILT LOAM—MITCHELL COUNTY. OSAGE FIELD—SERIES I.

Plot No.	Treatment	1918[1] corn bu. per A.	1919 corn bu. per A.	1920[2] oats bu. per A.	1921[3] clover tons per A.	1922[4] corn bu. per A.	1923[5] corn bu. per A.	1924[6] oats bu. per A.
1	Check	46.5	55.8	34.6	1.09	58.8	42.3	72.4
2	Manure	52.8	60.0	60.3	1.56	68.0	50.8	71.0
3	Manure+lime	52.8	70.0	56.3	1.98	68.0	64.1	82.8
4	Manure+lime+rock phosphate	54.8	72.0	61.2	1.94	74.3	70.7	86.5
5	Manure+lime+acid phosphate	56.4	77.0	61.2	1.82	76.0	70.7	98.0
6	Manure+lime+complete commercial fertilizer	44.5	79.0	67.3	1.63	72.3	70.2	102.9
7	Check	38.8	67.0	59.8	1.48	50.0	53.7	74.3
8	Crop residues	37.7	65.0	55.0	1.56	51.4	52.0	71.8
9	Crop residues+lime	39.4	74.0	50.3	1.56	58.3	65.2	81.6
10	Crop residues+lime+rock phosphate	47.4	75.0	61.8	1.56	57.7	64.4	90.3
11	Crop residues+lime+acid phosphate.	44.2	73.0	59.8	1.44	62.3	64.9	78.4
12	Crop residues+lime+complete commercial fertilizer	48.8	78.0	67.3	1.79	65.5	69.9	87.1
13	Check	39.7	67.0	53.1	1.60	52.3	53.2	75.6

[1]Four tons lime applied.
[2]Plot 1 low yield—oats down badly; four tons lime applied Sept.
[3]Clover pastured heavily in spring.
[4]Corn down badly on checks and crop residue plots.
[5]Dry weather reduced yield.
[6]Oats lodged. Gophers injured crop on plot 11.

TABLE XVIII. FIELD EXPERIMENT—MARSHALL SILT LOAM—MONTGOMERY COUNTY. RED OAK FIELD

Plot No.	Treatment	1918[1] W. wheat bu. per A.	1919[2] corn bu. per A.	1920 corn bu. per A.	1921[3] oats bu. per A.	1922[4] W. wheat bu. per A.	1923 corn bu. per A.	1924 soybeans bu. per A.
1	Check	13.6	52.0	56.0	28.2	13.2	54.5	11.2
2	Manure	34.1	57.2	61.6	36.9	15.5	57.8	12.4
3	Manure+lime	31.8	59.2	66.0	37.8	18.6	64.7	14.2
4	Manure+lime+rock phosphate	27.7	60.0	63.0	35.6	28.6	64.6	13.7
5	Manure+lime+acid phosphate	31.8	58.5	62.7	39.4	30.7	62.9	13.1
6	Manure+lime+complete commercial fertilizer	29.5	56.2	64.2	36.4	25.4	61.3	14.6
7	Check	....	54.2	56.6	31.8	17.4	50.6	10.5
8	Crop residues	29.5	51.0	54.1	31.3	16.4	52.9	9.9
9	Crop residues+lime	25.0	53.7	60.2	31.2	19.5	55.0	13.2
10	Crop residues+lime+rock phosphate	18.1	57.7	59.2	35.0	23.8	55.7	12.3
11	Crop residues+lime+acid phosphate	27.2	53.7	61.6	36.9	22.3	52.7	12.1
12	Crop residues+lime+complete commercial fertilizer	26.1	57.0	57.3	37.8	22.2	56.8	14.0
13	Check	13.6	48.2	51.4	29.0	15.2	52.0	8.9

[1]Clover killed and plowed up. Yield plot 7 error.
[2]3½ tons lime applied May 15.
[3]2½ tons lime applied in Sept.
[4]Dry weather killed out clover.

yields. Lime with the crop residues brought about considerable increases in yields in several instances, the effect being evidenced on the corn, oats and wheat as well as on the soybeans. Apparently this soil responds to applications of lime in the case of general farm crops as well as for legumes. The use of rock phosphate or acid phosphate with the crop residues and lime proved of value in most cases, the beneficial effect again being particularly evidenced on the winter wheat in 1922. The data indicates little difference in the effect of the two phosphates. In some cases acid phosphate seemed slightly superior but in other instances the rock phosphate was quite as satisfactory. The complete commercial fertilizer with the crop residues and lime was no more effective than the acid phosphate except in one or two cases where the differences were rather slight.

The data given in this table confirms the conclusions drawn from previous field experiments on the Marshall silt loam indicating the very large value of applications of farm manure, lime and a phosphorus fertilizer to this type. The soil will respond in a very large way to applications of farm manure and liberal amounts of this material should be used. The type is generally acid in reaction in the surface soil and the use of lime is very necessary in order to provide for the best growth of farm crops. Legumes are benefited to a very large extent by the use of lime. The application of a phosphate fertilizer seems to be of particularly large value on this soil, the beneficial effects being very pronounced in the case of many farm crops. Acid phosphate sometimes proves of larger value than rock phosphate but not in all cases. It would seem, therefore, that tests of acid phosphate and rock phosphate are very desirable on this soil before definite conclusions regarding the relative merits of the two fertilizers can be drawn. The complete commercial fertilizer used in this experiment did not seem to be any more preferable for use than acid phosphate inasmuch as in general it did not give any larger crop increases. When it did bring about slightly greater effects, the differences were not sufficiently large to warrant the use of the material because of its greater cost.

THE STORM LAKE FIELD

The results secured on the Webster silty clay loam on the Storm Lake field in Buena Vista County are given in table XIX. The application of manure to this soil type proved of large value as is evidenced by the results given in this table. Increases in crop yields were very pronounced in practically all seasons. The corn in 1920 and the clover in 1922 were increased particularly by the addition of manure. Considerable increases were noted in other seasons. Altho the type is very high in organic matter and black in color, it apparently will respond to applications of farm manure when properly made. This soil was basic in reaction and no lime was applied, hence plots 2 and 3 are duplicates.

The addition of rock phosphate or acid phosphate with the manure proved of considerable value in many cases. The beneficial effects of the two phosphate carriers were very much the same in some seasons. In other cases, however, the acid phosphate showed up better than the rock phosphate. This greater effect of acid phosphate was evidenced particularly on the corn in 1920 and on the clover in 1922. The oats in 1921 and the corn in 1919 also were increased more by the acid phosphate than by the rock phosphate. In 1918, however, the rock phosphate gave a greater effect than the acid phosphate. It would seem that in general the acid phosphate brings about slightly larger increases in crop yields than the rock phosphate. The complete commercial fertilizer with the manure had a greater effect than the acid phosphate in several cases. Only in one or two instances, however, were the differences very significant. In a few cases the complete fertilizer showed less beneficial effects than the acid phosphate.

The crop residues treatment on this soil had little effect in any of the seasons. No lime was applied so the yields on plots 8 and 9 may be considered as duplicates. The application of rock phosphate or acid phosphate with the crop residues brought about increases in crop yields in several cases. In general there was not a very large difference in the effects of the two phosphate fertilizers. In one or two cases the acid phosphate seemed to give larger effects and in other cases the rock phosphate was just as good or even slightly better. The differences were not large enough in any case to be of any considerable significance.

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

Plot No.	Treatment	1918[1] oats bu. per A.	1919 corn bu. per A.	1920 corn bu. per A.	1921 oats bu. per A.	1922[2] clover tons per A.	1923[3] corn bu. per A.	1924 corn bu. per A.
1	Check	73.0	54.7	48.2	45.1	0.75	51.0	22.7
2	Manure	73.0	54.1	57.3	42.2	1.01	60.7	27.5
3	Manure	73.0	57.6	58.1	36.3	1.29	65.1	29.2
4	Manure+rock phosphate	80.6	61.1	64.2	43.8	1.26	66.4	31.0
5	Manure+acid phosphate	74.5	66.4	76.5	51.8	1.42	68.5	31.8
6	Manure+complete commercial fertilizer	82.0	61.1	80.0	43.8	1.43	66.8	33.9
7	Check	70.0	71.5	66.6	40.9	1.10	55.8	34.0
8	Crop residues	85.1	75.7	67.6	49.1	1.08	63.3	37.3
9	Crop residues	76.0	70.1	67.2	41.1	1.25	70.7	35.7
10	Crop residues+rock phosphate	79.0	70.4	76.2	41.6	1.20	63.2	27.4
11	Crop residues+acid phosphate	73.0	64.0	76.2	45.5	1.23	63.1	31.1
12	Crop residues+complete commercial fertilizer	85.1	67.5	76.2	43.8	1.13	61.3	27.2
13	Check	79.0	67.5	67.7	39.7	0.86	51.9	23.1

[1]Soil basic; no manure applied; oats badly lodged.
[2]Acid phosphate and potassium applied to 3 and 9 in 1922. First crop only.
[3]Hogs in corn damaged yield.

The complete commercial fertilizer gave greater effects than the acid phosphate in one or two instances but in several cases showed less effect.

The results secured on the Webster silty clay loam in other fields are confirmed by the data given in this table. The beneficial effects of manure is evidenced on the type in spite of its high organic matter content. It would seem that small applications of manure might be made to this soil with very large effects on crop yields. Large amounts of manure should not be applied to the type and neither should the applications be made preceding the small grain crop of the rotation, owing to the danger of causing the crop to lodge. The application of a phosphate fertilizer to this type may be of very large value in most cases. The data given indicate that acid phosphate may be somewhat preferable to rock phosphate but definite conclusions cannot be reached regarding the relative merits of the two materials. It is recommended, therefore, that both phosphorus carriers be tested on this type in the field before any definite conclusions are reached. The application of a complete commercial fertilizer to this type does not seem to be any more effective than the use of acid phosphate. In general the results are quite as satisfactory with the use of the latter material. Because of its greater cost, very much larger increases in crop yields must be secured from the complete fertilizer if the material is to prove as profitable.

THE VILLISCA FIELD

The results secured on the Marshall silt loam on the Villisca field in Montgomery County are given in table XX. The beneficial effects of manure on this soil are evidenced by the data given in this table. The clover in 1918 and the corn in 1922 showed the most pronounced gain from the application of the manure. Increases were secured on all the other crops grown, however. The application of lime alone with manure increased crop yields further in practically all instances. The clover in 1918 showed a substantial gain and the same crop in 1921 was increased appreciably. The effect of the lime was not limited, however, to the clover but showed up on the corn and oats crop.

The addition of rock phosphate or acid phosphate with the manure and lime increased crop yields still more in most cases. Both materials increased the yields of clover in 1918. In 1921, the rock phosphate gave a gain in the clover but the acid phosphate had no effect. In 1920, the acid phosphate brought about a very large increase in the yield of oats but the rock phosphate had very little influence. In 1921, 1922, and 1923 the two phosphates brought about almost the same increases in crop yields. The complete commercial fertilizer with the manure and lime had a greater effect on the crops grown in some instances, showing up particularly well on the clover in 1918 and 1921, giving a greater effect than the acid phosphate in those years. In 1919, and 1920, however, lesser effects were evidenced by the complete commercial fertilizer than were secured by the use of a phosphorus carrier. In 1922 and 1923 there was very little difference in the effect of the two materials.

The crop residues had little or no effect on the yields of the various crops grown on this field. The lime applied with the crop residues brought about increased crop yields in several cases. The gains were not very large, however, altho they were evident on the oats and corn as well as on the clover crop. The rock phosphate or acid phosphate with the crop residues and lime gave increased crop yields in most instances. The greatest effect was evidenced from the acid phosphate on the corn in 1919, on the oats in 1920, and on the corn in 1922 and 1923. In the case of the clover in 1918 the rock phosphate seemed a little more effective. In general, however, the acid phosphate seemed to give greater results. The complete commercial fertilizer with crop residues and lime had a greater effect than the acid phosphate in several cases but did not show up quite as well in some other instances. The differences were not large in any case, however.

TABLE XX. FIELD EXPERIMENT—MARSHALL SILT LOAM—MONTGOMERY COUNTY, VILLISCA FIELD

Plot No.	Treatment	1918[1] clover tons per A.	1919 corn bu. per A.	1920[2] oats bu. per A.	1921 clover tons per A.	1922 corn bu. per A.	1923[3] corn bu. per A.	1924[4] corn
1	Check	1.00	49.3	46.2	0.73	64.1	37.7	....
2	Manure	1.20	51.0	52.1	0.88	73.9	38.8	....
3	Manure+lime	1.30	50.3	52.7	0.99	76.6	43.2	....
4	Manure+lime+rock phosphate	1.50	52.0	54.7	1.12	81.1	44.1	....
5	Manure+lime+acid phosphate	1.40	49.0	72.7	0.80	80.3	45.3	....
6	Manure+lime+complete commercial fertilizer	1.60	48.7	58.1	1.04	82.4	45.8	....
7	Check	1.65	52.0	49.3	0.93	63.3	38.0	....
8	Crop residues	1.60	49.3	47.9	0.91	63.3	37.9	....
9	Crop residues+lime	1.50	48.7	51.3	0.98	65.7	39.1	....
10	Crop residues+lime+rock phosphate	1.65	48.3	52.4	0.60	66.8	41.9	....
11	Crop residues+lime+acid phosphate	1.55	53.0	59.7	0.83	67.3	42.3	....
12	Crop residues+lime+complete commercial fertilizer	1.45	51.7	62.8	0.91	73.1	43.1	....
13	Check	1.55	55.7	51.4	0.70	64.9	36.6	....

[1]Clover stand not uniform.
[2]Limestone added for first time Sept. 25, 3½ tons.
[3]Hogs damaged corn on some of the plots.
[4]Crop failure.

The results secured on the Marshall silt loam on the Villisca field bear out the results secured on the other fields on the same type, indicating a very large value from applications of manure, lime and a phosphorus fertilizer. The increases in crops from the application of manure are very large. The soil is usually acid in reaction at least at the surface soil, and additions of lime will prove of large effect. The application of a phosphate fertilizer is very desirable on this soil. Acid phosphate seems to be somewhat preferable to rock phosphate in general, but in some cases rock phosphate gives quite as satisfactory results and definite conclusions regarding the merits of the two materials cannot yet be drawn. The data would indicate that the complete commercial fertilizer will have less beneficial effect on this type than acid phosphate.

AVERAGE RESULTS ON THE MARSHALL SILT LOAM

The average results secured on the Marshall silt loam on all the fields on this type in the state are given in table XXI. These figures show the average crop yields and the increase secured from the various fertilizer treatments applied on this soil. The value of manure on the corn, oats, clover and wheat on this type is very definitely shown, the effects being the greatest on the corn and the oats. Lime increased the yields of all the crops but showed up particularly well on the clover and wheat. The phosphates with manure and lime brought about distinct increases in all cases. The acid phosphate proved somewhat superior to the rock phosphate in every case. The difference was the greatest in the case of the clover crop. The complete commercial fertilizer had less effect than the phosphates on the corn, clover and wheat but gave somewhat greater effect on the oats, not enough, however, to make its use profitable.

The crop residues showed little effect on any of the crops grown. Lime with the residues brought about pronounced increases. The phosphates with the lime and crop residues both showed beneficial effects, the acid phosphate proving more effective than the rock phosphate. The greatest difference was noted in

the case of the oats crop. The complete commercial fertilizer had less effect than the acid phosphate in most cases. Only with the oats did it prove better than the rock phosphate.

It is evident from these figures that the Marshall silt loam may be profitably fertilized with manure, lime and phosphorus. The data secured on the individual fields on this type are thus confirmed by the average results given here. It appears that acid phosphate may be somewhat better than rock phosphate under both systems of farming, but the results along this line are not entirely definite and it is urged that tests of both fertilizers be carried out on individual farms in order that the farmer may use that material which will give him the best results. The complete commercial fertilizer had less effect than acid phosphate in practically all cases and hence it cannot be considered as desirable for use on this soil. Lime is evidently of value on this soil when it is acid and it is important, therefore, that the soil be tested for acidity and that lime be applied as needed.

THE NEEDS OF O'BRIEN COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

From the discussion of the laboratory, greenhouse and field experiments which has been given in previous pages, some general recommendations which are applicable to the soils of the county as a whole may be given. While the field experiments reported here have been carried out in other counties, the soil types are the same as those occurring in O'Brien County, and so it is believed that the results indicate quite definitely the results which will be secured from the same fertilizer treatments in this county. The recommendations which are given here are based on these experiments but they also reflect the general experience of many farmers. No suggestions are offered except those which have been proven to be of value by considerable practical experience. The recommendations made are such as may be put into effect on any farm.

In several cases it has been suggested that tests should be carried out on

TABLE XXI. MARSHALL SILT LOAM. AVERAGE CROP YIELDS AND INCREASE DUE TO FERTILIZER TREATMENT, IOWA EXPERIMENT FIELDS

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

*Corn yields averaged from four years' results on four fields; oats from four years' results on four fields; clover from one year's results on one field and winter wheat from one year's results on one field.

individual farms. Many farmers are already carrying out simple tests with fertilizing materials, securing data of much value to themselves and to other farmers who are located on the same soils. Such tests can be carried out quite readily. The Soils Section of the Iowa Agricultural Experiment Station is ready to aid any farmer who may be interested in carrying out fertilizer tests on their own soils.

LIMING

Most of the soils in O'Brien County are acid in reaction and, therefore, in need of lime. The Webster silty clay loam on the glacial uplands is basic in reaction in the surface soil and thruout the soil section. The Sioux loam on the terrace is basic in reaction in the surface soil and the Lamoure silty clay loam and the Lamoure loam on the bottoms are both basic in reaction. These types are not in need of lime and in fact they are very well supplied with lime at the present time. The Fargo silty clay loam on the terraces is basic in reaction in the subsurface soil and in many cases lime occurs at the surface of this type. The Clarion silt loam contains lime in the subsoil and the Marshall silt loam and the flat phase of the Marshall silt loam both show lime in the subsoil in some samples. The particular samples tested in this work contained lime in the subsoil. In many cases, however, the Marshall silt loam is acid thruout the three-foot section.

The needs of the surface soil must be considered to show most accurately the lime requirement of the particular soil type. Lime rarely moves upward in the soil but, on the other hand, the tendency is for it to be removed quite rapidly thru leaching in the drainage water and thru utilization by crops. The presence of lime in the subsoil does not mean, therefore, that it will not be desirable to apply lime if the surface soil is acid because the best early growth of some leguminous crops will not be secured in an acid surface soil. Except for the Webster silty clay loam on the uplands, the Fargo silty clay loam and Sioux loam on the terraces, and the Lamoure silty clay loam and Lamoure loam on the bottoms, the soils of O'Brien County may be acid in reaction and they should be tested especially before legumes are to be grown, if the best yields are to be secured. When the types are acid additions of lime should certainly be made.

The figures given in the tables show the average lime requirements of these various soil types but they should be considered merely indicative of the needs of the particular soils. Soils vary widely in acidity and lime requirement and even different samples of the same soil type may show a differing acidity. It is very important, therefore, that the soil in any field be tested for lime needs before an addition is made. In this way the proper application of lime may be made and the best results secured. Farmers may test their own soils for lime needs but it will usually be more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station where it will be tested free of charge and recommendations made regarding treatment.

The greenhouse and field experiments which have been described earlier in this report, have indicated some rather striking crop increases from the application of lime to the various soils tested. The evidence of beneficial effects of lime has been shown on the Carrington silt loam, on the Marshall silt loam and on the Waukesha silt loam. Beneficial effects have also been indicated on the Webster silty clay loam in a case where this particular type was acid in the surface soil. The beneficial effect of lime has been indicated also by much farm experience with the use of this material on acid soils. It is quite evident, therefore, that the acid soils in O'Brien County will respond in a very large way to applications of lime. Increases will be secured not only with leguminous crops but also with general farm crops altho ordinarily the largest effects from the use of lime are evidenced on the legume crops of the rotation. Further information regarding the use of lime on soils, losses by leaching and other points

connected with liming, are given in Extension Bulletin 105 of the Iowa Agricultural Experiment Station. A list of companies prepared to furnish this material is also given in this bulletin.

MANURING

Many of the soil types in O'Brien County are apparently very well supplied with organic matter. Only the Dickinson fine sandy loam on the glacial uplands shows any noticeable deficiency in organic matter. Even the Marshall silt loam on the loessial uplands is apparently fairly well supplied with this constituent. It would seem, however, from the experimental data reported earlier, that many of these soil types will respond in a very large way to the application of fertilizing materials supplying organic matter. Considerable increases in crop yields are quite generally secured from the application of farm manure. This is true, not only in the case of those soil types which are not so rich in organic matter, but also with those soils where the supply of organic matter is high and the color of the soils is black. Even the Webster silty clay loam on the glacial uplands and the Lamoure silty clay loam on the bottomlands will respond to the proper application of farm manure in small amounts. On these heavier textured, darker colored soils, the application of manure should not be made preceding the small grain crop in the rotation owing to the danger of causing the crop to lodge. The amount of manure used in such cases may also be reduced considerably.

It is important, therefore, to utilize the farm manure produced on every farm in order to insure the largest crop yields on the various soils. Not only does the farm manure increase the returns from the various crops grown but it aids in a very large way in maintaining the supply of organic matter and other plant food constituents in the soil. Even those types which are well supplied with organic matter will gradually lose their content and become deficient and it is very important that some means be taken to keep up the supply of organic matter in all soils. Farm manure is obviously the material which can be used to the best advantage in such cases.

The usual application of manure to soils is about 8 to 10 tons per acre once in a four-year rotation. It is rarely desirable to make larger applications than this except in the case of very light textured soils or where special crops are to be grown. For general farm crops the largest increases in crop yields per ton of manure are secured with the 8 to 10 ton application.

Green manuring may be a very important farm practice on many of the farms in O'Brien County. On grain farms, where farm manure is not produced, the use of leguminous crops as green manures is very important. On many livestock farms it may also be necessary because often insufficient manure is produced to supply all of the soils regularly. In order to secure the best crop yields, and to maintain the supply of organic matter, leguminous green manure crops should be grown as a supplement to farm manure or as a substitute for that material. Leguminous crops used as green manures have the further value that they take nitrogen from the atmosphere when well inoculated and hence when they are turned under in the soils they increase the supply of this constituent. The practice of green manuring with leguminous crops, therefore, has a double value in keeping up the supply of organic matter and nitrogen. The practice would undoubtedly prove of considerable value on many of the soils of O'Brien County. Care should always be taken, however, in following the practice, as undesirable results may occur if conditions in the soil are not satisfactory for the best decomposition of the green materials.

Crop residues should always be returned to the land as they contain considerable amounts of plant food and much organic matter and hence they serve in a very large way to maintain the supply of plant food constituents and or-

ganic matter. If the residues are burned or otherwise destroyed there is an actual destruction of valuable fertilizing constituents. On the livestock farm, the residues may be used for feed or bedding and returned to the land with the manure. On the grain farm, they may be stored and allowed to decompose partially before being applied or they may be applied directly to the land.

THE USE OF COMMERCIAL FERTILIZERS

The phosphorus content of the soils of O'Brien County is quite generally low and it seems evident that phosphorus fertilizers will be needed on these soils in the very near future. The data given earlier in this report, however, show that they will respond in a very large way to the application of a phosphorus fertilizer at the present time. The results secured in the greenhouse and field experiments and on the soils in adjacent counties where the soil types are the same have indicated very large increases in the yields of general farm crops from the use both of acid phosphate and of rock phosphate. In many cases the acid phosphate has been of superior value to the rock phosphate but in other cases the rock phosphate has apparently given quite as large an effect.

Acid phosphate provides the element phosphorus in a form which is immediately available. Rock phosphate, on the other hand, contains the phosphate in a form which must be changed in the soil to be available. This process goes on rather slowly under some soil conditions. Acid phosphate is more expensive than the rock phosphate but the application of the material is smaller. Acid phosphate is usually applied at the rate of 150 to 200 pounds per acre annually while rock phosphate is added at the rate of one ton per acre once in a four-year rotation. To determine the relative value of the two materials, therefore, comparative tests should be conducted over at least a four-year period and the total cost of the applications of the two materials taken into account.

From the data given in this report, it is impossible to draw definite conclusions regarding the relative value of the two phosphate fertilizers on the soils of this county. It is urged, therefore, that farmers test both phosphate fertilizers on their own soils and thus determine for their own conditions which material will prove the more profitable. Simple tests can be carried out quite readily on any farm. Directions which may be followed in conducting such tests are given in Circular 82 of the Iowa Agricultural Experiment Station.

The supply of nitrogen in the soils of O'Brien County is generally quite large but in a few cases there is apparently a deficiency in this element. In all of the soils, however, care must be taken that some fertilizing material supplying nitrogen be added to the soils regularly if the supply is to be kept up. In no case is the content sufficient that nitrogen may be ignored in planning systems of permanent fertility for the soils of the county.

The most important nitrogenous fertilizer is farm manure. On the livestock farm the proper preservation and application of the manure will aid materially in maintaining the nitrogen supply. On the grain farm some other nitrogenous fertilizer must be employed and in many cases additional means must be used on the livestock farm to insure the maintenance of an adequate supply of nitrogen. In both these cases the use of leguminous crops as green manures is a very desirable practice.

When a legume crop is inoculated, as it always should be, a large part of the nitrogen in the crop is taken from the atmosphere and when the crop is turned under in the soil as a green manure there will be a corresponding increase in the nitrogen content in the soil. Undoubtedly in many cases in O'Brien County turning under legumes as green manures would be of value in increasing the supply of nitrogen in the soil as well as in building up and maintaining the content of organic matter. The proper utilization of crop residues also aids considerably in maintaining the supply of nitrogen in the soils.

Commercial nitrogenous fertilizers can hardly be recommended for general use on the soils of O'Brien County at present. While no striking deficiency in nitrogen exists, materials containing nitrogen should be regularly used on these soils to prevent any deficiency from occurring. The proper use of farm manure, leguminous crops as green manures, and crop residues, will provide the nitrogen that is needed on these soils and permit of the maintenance of the supply indefinitely.

The potassium present in the soils of O'Brien county is very large and the supply of this element is sufficient to keep crops supplied for many years to come. It seems unlikely that potassium fertilizers will be of any particular value on these soils. All that is needed to insure proper conditions for the transformation of the potassium in the soils into an available form are proper drainage and cultivation, the application of lime and the supplying of liberal amounts of organic matter. Enough potassium is present in these soils to supply the needs of crops for many years to come if the material is changed into an available form sufficiently rapidly. Potassium fertilizers cannot be recommended, therefore, for general use in this county, and only when applied in small amounts as top dressings does it seem possible that they might prove of profit.

From the tests conducted on the soils of O'Brien County, it would not seem that complete commercial fertilizers would be superior to acid phosphate for use on these soils. In many cases the acid phosphate seemed to give quite as large increases in crop yields and in no instance did the complete commercial fertilizer bring about a sufficiently larger increase to warrant the greater cost of the material. Nitrogen may be supplied to the soils of the county more cheaply thru the use of legumes as green manures and by the application of farm manure and the utilization of crop residues. Potassium is not likely to be deficient, hence the chief value of the complete commercial fertilizer lies in the phosphorus content. It would seem, therefore, that acid phosphate should prove quite as desirable for use. Tests may be carried out with these materials, however, in comparison with acid phosphate by any farmers who are interested and if they secure profitable returns from the application of the complete fertilizers, there is no objection to their use.

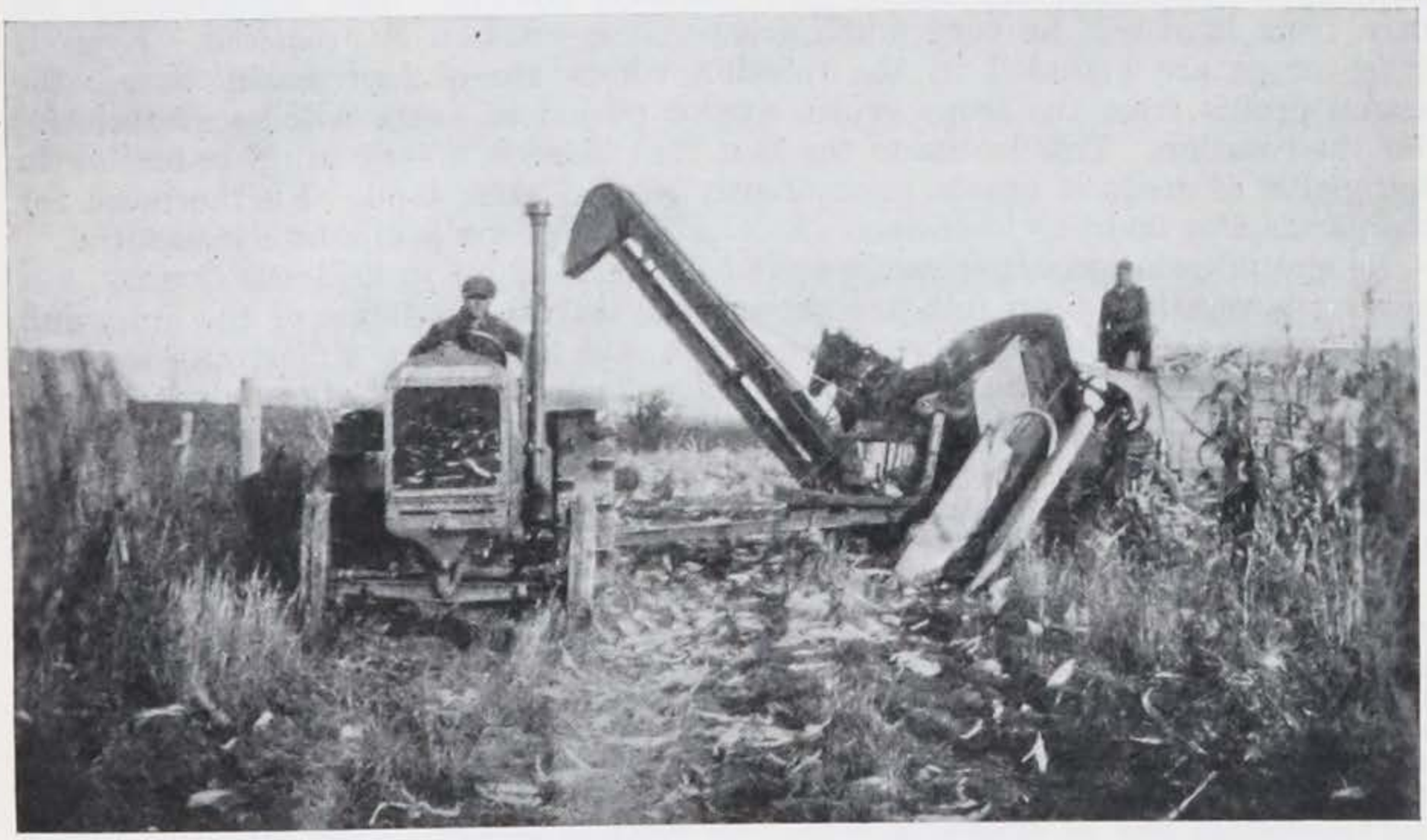


Fig. 10. A corn harvesting scene, O'Brien County.

DRAINAGE

The drainage conditions over a large part of O'Brien County are quite adequate but in many areas the natural drainage system is very poorly developed and large areas of soil are not adequately drained. On the level area east of Waterman Creek there is practically no natural drainage and the need of artificial drainage is very definitely shown here. In many other areas in the county, drainage conditions are not entirely satisfactory and the installaton of tile or the location of a drainage ditch is very necessary in order to bring about the best conditions for crop growth.

Usually a rather definite relationship exists between the need for drainage and the particular soil type. Thus the Webster silty clay loam is very poorly drained. On the terraces, the Fargo silty clay loam shows a need for drainage and on the bottoms the Lamoure types are in need of drainage. In some areas in the flat phase of the Marshall silt loam, drainage is not entirely satisfactory but usually the Marshall is fairly well drained.

When the soil is too wet good crop yields cannot be secured. The first treatment needed on such land is to insure thoro drainage either by the installation of tile or if necessary by the location of a drainage ditch. In many parts of O'Brien County crop yields are not entirely satisfactory at present because of the lack of thoro drainage. Tiling may be an expensive operation but the results secured always warrant the outlay. The farmers in this county should see that their land is thoroly drained if they wish to secure the best returns. No fertilizing treatment will have any value on land which is too wet and fertilizers may be wasted if they are applied to poorly drained areas. An abundance of experimental data is available which shows the benefits from tiling out land which is not properly drained and in many cases it may mean the difference between no crop at all and a very satisfactory crop yield.

THE ROTATION OF CROPS

It is well known now that the continuous growing of any one crop will quickly reduce the fertility of the soil. In spite of this general knowledge, however, farmers still continue to grow one crop continuously on land due to the fact that the particular crop may be the money crop. Experimental evidence and much experience has shown quite clearly, however, that the economic return from land will be very much greater if a rotation is practiced. Even if other crops are included in the rotation which are of less money value, the actual profits from the crops grown over a period of years will be greater under the rotation. This is due to the fact that there is a very rapid reduction in the yields of crops if grown continuously on the same land. Furthermore for the permanent fertility of the soil the rotation of crops is absolutely essential.

No special rotation experiments have been carried out in O'Brien County, but numerous rotations been followed successfully in various parts of the state and from among these one may be chosen which will fit in with almost any average farm conditions. No one rotation can be recommended for all conditions and, indeed, almost any rotation will prove satisfactory provided it contains a legume crop and a money crop. The following examples of rotations which are in common use thruout the state may serve as a basis on which rotations suitable for O'Brien County may be worked out.

1. SIX-YEAR ROTATION

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

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

2. FOUR OR FIVE-YEAR ROTATION

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

3. FOUR-YEAR ROTATION WITH ALFALFA

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

4. FOUR-YEAR ROTATIONS

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

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

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

5. THREE-YEAR ROTATIONS

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

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

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

THE PREVENTION OF EROSION

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

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Gullying is more striking in appearance but it is less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes.

Erosion occurs to a considerable extent in some of the types in O'Brien County. It is particularly evidenced on the steep phase of the Clarion loam and on certain areas of the Marshall silt loam, the Clarion silt loam and the Carrington silt loam. Some washing also occurs in the case of the Dickinson

fine sandy loam. Serious washing away of the surface soil often occurs and gullying is rather common, and where these effects of erosion are noted, some means of prevention or control of this destructive action should be adopted.

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

EROSION DUE TO DEAD FURROWS

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

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

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

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

SMALL GULLIES

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

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

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

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

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

The "Christopher" or "Dickey" Dam.—This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam. An elbow or a "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or

board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass.

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

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

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

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

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

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

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

LARGE GULLIES

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

BOTTOMLANDS

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

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

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

HILLSIDE EROSION

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

Use of Organic Matter.—Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts.

Crop residues such as straw and corn stalks may also be turned under in soils to increase their organic matter content.

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

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

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

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

INDIVIDUAL SOIL TYPES IN O'BRIEN COUNTY* **

There are 15 soil types in O'Brien County and these with the flat phase of the Marshall silt loam make 16 separate soil areas in the county. They are divided into four groups on the basis of their origin and location, known as drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are five drift soils in the county classified in the Clarion, Carrington, Webster and Dickinson series. Together they cover 72.8 percent of the total area of the county.

CLARION SILT LOAM (169)

The Clarion silt loam is the most extensive drift soil in the county and the second largest soil type. It covers 7.8 percent of the total area. The type is extensively developed in the eastern part of the county in Hartley and Omega Townships. Considerable areas are also found in Grant Township. The largest development of the type is in the northeast corner of the county across Hartley Township. Other large areas occur southeast of Hartley and thru the cenfer of Omega Township along Waterman Creek. Small areas of the type are also found along Mill Creek and some of its eastern tributaries in the central part of the county and very small areas of the type occur along the Floyd and Little Floyd Rivers.

The surface soil of the Clarion silt loam is a dark brown to black silt loam, extending to a depth of 12 to 14 inches. Below this point, there is a layer of 4 to 6 inches of a dark brown heavy silt loam to silty clay loam which passes at a depth of 16 to 20 inches into a light brown to yellowish or grayish-brown silty clay. Rusty brown, gray and yellow stains and lime concretions occur in the subsoil. Sand and gravel occur in general thruout the subsoil and boulders are occasionally found on the surface soil and thruout the three foot section. Small areas of the Marshall silt loam and the Carrington silt loam are included with the Clarion silt loam as they are too small to separate on the map. In spots

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*"O'Brien County adjoins Clay County on the east and Sioux County on the west. In certain cases the maps of these counties do not appear to agree along the boundaries. This is mainly due to changes in correlation resulting from a fuller knowledge of the soils of the state. Some of the areas formerly mapped with the Carrington series are now mapped with the Clarion soils and the Shelby with the new Dickinson series. The Lamoure soils are more accurately defined and their areas now include areas formerly classed with the Wabash series."—Bureau of Soils Report.

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

too small to map, the subsoil consists of loose gravel. Areas of the type which occur adjacent to the Webster silty clay loam are a heavy silt loam in the surface soil and have a more plastic and compact subsoil, in places approaching the subsoil of the Webster. Boundary lines between these types are established in some cases rather arbitrarily. In the areas along the lower course of Mill Creek in Union Township, the surface soil frequently contains considerable proportions of fine sand.

In topography the Clarion silt loam is gently rolling, occurring in very much the same topographic position as the Carrington silt loam. Where the two types are adjacent, however, as is true in the eastern part of Grant Township, the Clarion silt loam occurs on the slope position between the higher lying Carrington silt loam and the bottomlands. In Section 10 and 11 of the same township, the Clarion silt loam occurs in an intermediate position between the level Webster silty clay loam and the high Carrington silt loam. The type also occurs on isolated elevations on the Webster silty clay loam level area in section 23 of Omega Township. It is sometimes found also in intermediate positions between the steep phase of the Clarion loam and the bottomlands along the creeks in Waterman and Grant Townships. The drainage of the type is well established except on the nearly level areas where in a few cases the drainage is inadequate. In the areas along some of the larger streams the slopes are occasionally rather steep and erosion has occurred to some extent.

The Clarion silt loam is all in cultivation. Corn, oats and hay are the chief crops grown. Corn yields 40 to 45 bushels per acre; oats, 35 to 40 bushels; barley, 25 to 30 bushels; winter wheat, 15 to 20 bushels; clover and timothy hay, 2 to 2½ tons per acre; alfalfa, 3 to 4 tons per acre; timothy alone, 1 to 1½ tons per acre; and wild hay, about the same.

Yields of general farm crops on the Clarion silt loam are generally quite satisfactory but in many cases very large increases in crops may be secured thru the application of proper fertilizers and thru proper treatment. The application of manure is of very large value and liberal amounts of this material should be used wherever possible. While the type is acid in reaction at the surface soil, it is quite evidently in need of lime for the best growth of crops and particularly of legumes. It contains some lime in the subsoil but this is not sufficient to change the needs of the surface soil and it is very important that the soil be tested for lime needs and the amount required be applied before legumes are to be grown. Increases in the yields of general farm crops are also secured from the application of lime to this type in many cases.

The beneficial effects of a phosphate fertilizer on the soil are shown very definitely by experiments and some farm experience. The results with acid phosphate and rock phosphate are very similar and it is impossible from the data thus far available to determine which phosphate fertilizer would prove the more profitable. It is recommended, therefore, that farmers test both acid phosphate and rock phosphate on their own farms and thus determine for their conditions which fertilizer is the more satisfactory. The use of a complete commercial fertilizer on the type cannot be recommended as it would seem that acid phosphate would probably be quite as satisfactory. Where the type is not entirely adequately drained the installation of tile is very desirable and on those steeper slopes where erosion has occurred to a considerable extent, some means should be taken to prevent the serious washing away of the surface soil.

CARRINGTON SILT LOAM (83)

The Carrington silt loam is the second largest drift soil in the county and the fourth soil in area. It covers 3.3 percent of the county. It occurs mainly in the eastern and southeastern parts of the county separating the level areas of the Webster silty clay loam from the drainage to Waterman Creek on the west. The largest developments of the type are found southeast of Hartley in

Omega Township and along the east side of Waterman Creek in the center of Grant Township. Areas also extend down to the county line thru Waterman Township. Small areas of the type are present in other parts of the county, notably in Waterman Township west of the creek and near Primghar, Paullina and Calumet.

The surface soil of the Carrington silt loam is a dark brown to black mellow silt loam 10 to 12 inches in depth. The subsoil is a brown to dark brown friable clay loam grading at 18 to 20 inches into a light yellowish-brown or light brownish-yellow more compact heavy clay loam to silty clay loam, containing varying quantities of sand and gravel. In places the lower subsoil is stained with rusty brown, yellow and gray. Boulders are rather numerous thruout the soil section and frequently on the surface. In places the texture of the surface soil varies from a heavy loam to a heavy silt loam or loam. The lighter textured soil is usually underlaid by a more friable subsoil containing more sand and gravel. Where these coarser materials occur in sufficient quantities, the subsoil is a coarse sandy clay to sandy clay loam with a structure approaching the Dickinson subsoil. The heavier surface soil variations are underlaid by a more uniform textured and heavier subsoil which is less friable and rather compact. In topography, the Carrington silt loam is gently rolling to rolling. The natural drainage of the type is very well established. Erosion occurs to some extent on the steeper areas of the soil.

All of the type is in cultivation, corn and oats being the principal crops grown. Barley and wheat are grown in a small way on the soil. The yields of general farm crops are very much the same as those secured on the Clarion silt loam. The soil will respond in a very large way to applications of farm manure just as was noted with the Clarion silt loam. The experiments given earlier in this report show very definitely the very large effects of applications of farm manure to this soil in increasing the yields of general farm crops. The type is acid in reaction and applications of lime are very desirable. Large gains in the yields of leguminous crops result from the addition of proper amounts of lime.

The application of a phosphorus fertilizer will prove of profit on the soil as has been indicated by the experiments reported and by some experience. Whether acid phosphate or rock phosphate should be applied cannot now be definitely stated as the results secured for the two materials seemed to be variable, depending on the particular conditions under which the test has been carried out. It is recommended, therefore, that farmers test both acid phosphate and rock phosphate for their own particular conditions to determine which will be the more profitable for general use.

WEBSTER SILTY CLAY LOAM (107)

The Webster silty clay loam is the third largest drift soil in the county and the fifth type in area. It covers 3.2 percent of the county. It occurs mainly in the extreme eastern part of the county in Omega and Grant Townships. The largest area covers a large part of Omega Township extending to the county line and over the township line into Grant Township and down thru that township in the eastern section to the northeast section of Waterman Township. Small areas of the type also occur in the north central sections of Hartley Township and in the vicinity of Sanborn and along the north county line directly north of Sanborn.

The surface soil of the Webster silty clay loam is an almost black silty clay loam, extending to a depth of 10 inches. The subsurface layer is a dark grayish-brown to black heavy silty clay loam to silty clay loam, changing at 20 inches into a silty clay somewhat mottled and more plastic. The subsoil below 20 inches is a yellowish-brown plastic silty clay heavily mottled with gray and rusty brown and containing lime concretions and calcareous material. Sand

and gravel occur in the subsoil and a few boulders are found on the surface and thru the soil section. In the areas where the Webster silty clay loam is closely associated with the Clarion and Carrington silt loams, the subsurface layer consists of a well oxidized yellowish-brown silty clay loam. Small areas of the Clarion and Carrington silt loams which are too small to show on the map, are included with the Webster silty clay loam. In some places the surface soil contains a very large amount of coarse sand and approaches a clay loam or a heavy coarse loam in texture.

The Webster silty clay loam has an undulating to level topography, in the large areas in the eastern part of the county. The smaller areas in the north and north central parts of the county occur in depressed areas in the Marshall silt loam uplands. Natural drainage is poor due to the level to flat topography of the type and to the heavy characteristics of the subsoil.

All of the type is under cultivation or utilized for pasture and hay land. Corn is grown most extensively on the cultivated areas and the most important hay crops consist of timothy and clover mixed, timothy alone, clover and alfalfa. Small grains are grown to a limited extent. These consist mainly of oats, barley and wheat. Wild hay is produced on the poorly drained water-logged spots. Bluegrass grows very well on the type. Millet, sorghum, rape, rye and buckwheat are sometimes grown. On the well drained areas corn yields 50 to 60 bushels per acre; oats, 35 to 40 bushels; timothy and clover, 2 to 2½ tons; timothy alone, 2 tons; clover alone, 2½ tons; and alfalfa, 3 to 3½ tons per acre.

The chief need of the Webster silty clay loam to make it more satisfactorily productive is thoro drainage. The installation of tile is very necessary in order to permit of the best growth of cultivated crops. When the type is well drained it must be carefully cultivated in order to prevent the establishment of poor physical conditions. If it is plowed when it is too wet, it is apt to clod. Frequent cultivation is very desirable. Corn and hay crops are most successfully grown as in some cases the small grains are apt to lodge. The type will respond to applications of farm manure as has been indicated by the experiments discussed earlier in this report and by much farm experience. Small amounts of farm manure have a very large value on the type when it is newly drained. Manure should not be applied on the soil immediately preceding the growth of small grain crops owing to the danger of causing them to lodge. Even when such crops are grown, however, small amounts of manure are of value if supplied at other places in the rotation. The soil is not usually acid in reaction and frequently is high in lime. When it is acid, however, applications of lime will be of value as has been indicated in some of the experiments reported earlier. Applications of a phosphate fertilizer will bring about very profitable returns on the type and farmers are urged to test the value of acid phosphate and rock phosphate under their own conditions. It seems from the experiments reported earlier that acid phosphate may be somewhat preferable for use but definite conclusions should not be drawn until tests have been carried out on the particular area.

CLARION LOAM, STEEP PHASE (151)

The steep phase of the Clarion loam is the fourth drift type in area in the county and the sixth soil in extent. It occurs chiefly on the slopes along the Little Sioux River and Waterman Creek in Grant and Waterman Townships. There are no large individual areas of the type. It occurs in narrow irregular shaped areas bordering the streams mentioned. The largest individual development of the type is southeast of Sutherland along Dog Creek.

The surface soil of the steep phase Clarion loam is a dark brown mellow loam to heavy loam extending to a depth of 10 inches. The subsoil is a light brown to dark brown heavy loam to clay loam becoming lighter in color and heavier in texture at the lower depths. Below 18 to 20 inches it is a light to dark yellowish-brown, or grayish-brown coarse clay loam to silty clay loam, containing con-

siderable amounts of sand and gravel. Lime concretions occur in the lower part of the subsoil. There are many variations in the characteristics of the surface soil and even of the three-foot soil section, due to the occurrence of erosion and the washing which occurs on the type. In some cases the underlying glacial sand and gravels are exposed. The texture of the surface soil may range from a clay loam to a loam, the subsoil from a loose porous sand, gravel or rock fragments to a very compact friable silty clay.

In topography the steep phase of the Clarion loam is abrupt to precipitous. Erosion is very active and very difficult to control. The topography of the soil is so rough that it is impossible to bring it under cultivation. Some areas are still forested with elm, bur oak, basswood, box elders, ash, hard maple, soft maple, wild plum, crab apple and hawthorne. The type is used for pasture purposes only and this consists of native prairie grasses. Bluegrass stands are poor. The type is suitable only for pasture.

DICKINSON FINE SANDY LOAM (175)

The Dickinson fine sandy loam is a minor type in the county, covering only 0.1 percent of the total area. It occurs in several small areas along the upland slopes to Mill Creek in Dale and Union Townships. Other areas which are too small to show on the map occur in similar position within areas of the Clarion loam, steep phase, along Waterman Creek and Little Sioux River. Two small areas occur in section 7, Union Township, and in section 23, Caledonia Township, occurring on low hill positions standing out prominently above the surrounding uplands.

The Dickinson fine sandy loam has a surface soil of a dark brown, moderately loose fine sandy loam to light loam extending to a depth of 14 to 16 inches. The subsoil is a light yellowish-brown very light sandy clay to heavy sandy clay loam. Sand occurs occasionally in the lower subsoil at 30 to 36 inches. The subsoil is usually more porous and loose and lighter in texture at the lower depths. In some places it approaches a sand or light sandy loam. In a few areas occurring in Union Township and Caledonia Township mentioned above, the subsoil consists mainly of coarse sand and gravel.

The topography of the Dickinson fine sandy loam is rolling and drainage is entirely adequate. In fact in periods of low rainfall, crops are likely to suffer from drouth. The type is subject to considerable erosion.

Most of the Dickinson fine sandy loam is utilized for pasture or hay land. A small part of it is under cultivation and corn and small grain crops are grown. Yields of cultivated crops are lower than those secured on the adjacent upland soils, and hay and pasture grass s frequently suffer in periods of low rainfall. The type when cultivated is particularly in need of organic matter to increase the content in the soil and to prevent the rapid drying out and the occurrence of drouth effects on the crops. The soil is acid and would respond to applications of lime. It is low in phosphorus and additions of a phosphate fertilizer would undoubtedly prove of value.

LOESS SOILS

There are two loess types in the county, the Marshall silt loam and the flat phase of the same type. Together they cover 72.8 percent of the county.

MARSHALL SILT LOAM (9)

The Marshall silt loam is the most extensive individual soil type in the county. Together with the flat phase which is very small in area, it covers almost three-fourths of the county. It occurs over the uplands in broad areas thruout the county, being the most important upland type except in the extreme eastern part of the area. Large unbroken areas of the soil occur in all parts of the county. Thruout the north central part of the county there are small areas of the Web-

ster silty clay loam and of the Fargo silty clay loam occurring in the more rolling Marshall uplands. As it approaches the streams areas of Clarion silt loam separate it from the bottoms or the streams themselves. In other places it occurs immediately adjacent to the terrace soils or the bottomland soils along the streams or the tributary streams.

The surface soil of the Marshall silt loam is a dark brown to black mellow silt loam, extending to a depth of 12 to 14 inches. The subsoil is a dark yellowish-brown crumbly heavy silt loam to clay loam, changing at about 20 inches into a light yellowish-brown or grayish-brown to brownish-yellow heavy plastic silt loam to light silty clay loam. In many areas there is a considerable content of lime in the subsoil. In the more rolling areas, the subsoil does not contain this calcareous material in appreciable quantities until much lower depths are reached. In these rolling areas the surface soil is somewhat shallower and lighter in color, containing less organic matter. The subsurface soil and subsoil are also somewhat lighter in color and ordinarily there is a somewhat higher percentage of very fine sand and fine sand in the lower subsoil. In some of the more level areas the lime content of the subsoil is low and in places entirely absent. In section 5 of Waterman Township, the surface soil is a dark brown to black in color, the subsoil is a heavy clay loam to silty clay loam, plastic and very compact, showing rusty brown to yellow mottlings in the lower part and containing no lime whatever. Another extensive area similar in topography and with a similar surface soil and subsoil condition, occurs adjacent to Mills Creek in sections 3, 10, and 15, of Dale Township and another in section 26 of Summitt Township.

Varying amounts of fine sand occur thruout the surface soil in the more rolling areas adjacent to the Floyd and Little Floyd Rivers, and over the entire areas in Waterman, Liberty, East Union and western Highland Townships and in Grant Township west of Waterman Creek. In sections 1 and 2 of Floyd Township the surface soil is a grayish-brown to dark brown mellow, heavy loam to silt loam. At 10 to 12 inches it contains larger amounts of fine and very fine sand increasing at the lower depths until, at 20 to 22 inches, the subsoil becomes a light yellowish-brown very compact friable fine to very fine sandy clay to clay loam. The loess is the purest in the western part of the county, becoming less pure toward Waterman Creek in the more rolling and well drained areas in the southern and eastern parts of the county. Usually the underlying drift material is not encountered until depths of 5 to 10 feet are reached. Where the topography is undulating to depressed, the glacial material is reached, however, from 32 to 40 inches. Such areas occur in Lincoln, Northwestern and Center Townships and in other places in association with the flat phase of the Marshall silt loam adjacent to the Clarion, Carrington and Webster soils as in Hartley Township.

In topography, the Marshall silt loam is typically undulating to gently rolling, in a few places becoming rolling. Natural drainage of the type is very well established altho, in the more gently undulating areas, surface drainage is slow. In the rolling areas, where the subsoil characteristics make the type more porous, drainage is apt to be excessive and occasionally crops suffer from drouth.

Practically all of the Marshall silt loam is under cultivation. The chief crops grown are corn, oats, barley, wheat and hay. About 35 percent of the type is utilized for corn which yields from 25 to 75 bushels, or an average of about 45 bushels per acre. Oats occupy an acreage of 25 percent of the type and yield 25 to 55 bushels or an average of about 40 bushels per acre. Barley yields 25 to 30 bushels and spring wheat, 15 to 20 bushels. Winter wheat which is grown to a limited extent, yields about the same as spring wheat. Timothy and clover mixed produce 2 to 2½ tons per acre; timothy alone, 1 to 1½ tons; clover alone, 2½ tons; and alfalfa, 3 to 4 tons per acre. Hay crops are grown on about 10 percent of the area. About 20 percent is utilized for pasture land which is chiefly in bluegrass, timothy and some native prairie grasses. Minor crops

grown in the county include besides wheat and barley, rye, sorghum, millet, rape, soybeans, buckwheat, flax and potatoes.

Average crop yields on the Marshall silt loam are apparently quite satisfactory but very large increases in yields may be secured thru proper soil treatment. The type responds in a very large way to applications of farm manure. The experiments discussed earlier in this report indicate quite definitely the large effect from the applications of this material. Increases in the yields of all general farm crops are practically always secured. It is undoubtedly one of the most important fertilizing materials which can be used on the soil. The turning under of leguminous crops as green manures would be of very considerable value in many areas of this type. It is particularly important to utilize leguminous crops as green manures on grain farms or on farms where there is insufficient production of farm manure to keep all the land supplied regularly.

While many areas of the Marshall silt loam show a lime content in the subsoil, the surface soil of the type is usually acid in reaction. Experiments indicate that applications of lime to the surface soil are very desirable when the type is acid, if the best early growth of leguminous crops is to be secured. It would seem that the application is desirable even if there is a lime content in the lower soil layers. This is especially true if clover, alfalfa or sweet clover are to be grown.

The type is not very well supplied with the phosphorus and applications of a phosphate fertilizer would be of very large value. The experiments described earlier in this report indicate a very large effect from the application of a phosphorus carrier. In many cases acid phosphate seems to be somewhat preferable for use over rock phosphate but in a few instances, rock phosphate has shown up very well. It would seem, therefore, that definite conclusions regarding the relative value of these two materials should not be drawn until experiments have been carried out on individual farms. It is urged, therefore, that farmers test the effect of acid phosphate and rock phosphate on their own soils and thus determine for their particular conditions which will prove the more profitable. Complete commercial fertilizers are not recommended for general use on the soil as it is thought that acid phosphate will probably prove more profitable. There is no objection to the use of complete fertilizers, however, if tests are carried out and they are found to be of more value than acid phosphate.

MARSHALL SILT LOAM (FLAT PHASE) (74)

The flat phase of the Marshall silt loam occurs chiefly in Hartley, Center and Lincoln Townships. The largest development of this type is east of Primghar in Center Township. Other small areas occur in other parts of the county.

The surface soil of the flat phase of the Marshall silt loam is a black heavy silt loam, extending to a depth of 8 to 10 inches. The subsoil is a dark gray to black heavy, plastic silty clay loam to a depth of 16 to 20 inches. Below that point, it becomes a grayish-yellow semiplastic to plastic silty clay loam. Below 30 inches, the subsoil is faintly mottled with yellow, brown and rusty brown and usually contains lime concretions and calcareous material. Below 36 inches, there is frequently some coarse sand and gravel from the underlying drift. In many places the lime concretions and calcareous material do not occur within the three foot section. The phase differs from the typical Marshall silt loam in having a shallower surface soil and a somewhat heavier structure to the surface soil, and a more poorly oxidized and heavier subsoil. There are gradual changes from the phase into the typical Marshall silt loam, into the Fargo silty clay loam and into the Webster silty clay loam. In several cases the boundary lines between these types are rather arbitrarily drawn.

In topography the flat phase of the Marshall silt loam is level to flat as the name indicates. Some of the areas occupy slight depressions while the larger

areas such as those in Hartley Township occur on the level to very gently sloping uplands. Drainage of the type is quite inadequate.

All of the soil is in cultivation and general farm crops are grown, chiefly corn and hay. Some of the area is used for pasture and small grains are grown to some extent. The yields of cultivated crops are somewhat lower than those secured on the typical Marshall silt loam, particularly in wet seasons. Hay yields are a little higher and pastures are very readily maintained.

The chief need of the flat phase of the Marshall silt loam is for drainage. Tiling should be practiced on these areas before the land is cultivated if satisfactory crop yields are to be secured. After thoro drainage of the areas has been accomplished very satisfactory crop yields will usually be secured. The phase will respond, however, to small applications of farm manure for the growth of corn and hay crops. The type is usually acid in reaction in the surface soil and applications of lime are very necessary especially for the best growth of legumes. The content of phosphorus is low and additions of a phosphate fertilizer would be very desirable on the soil. Acid phosphate might be more preferable for use but in some cases rock phosphate would probably do quite as well. It is recommended that tests of acid phosphate and rock phosphate be carried out on the soil to determine which will be more profitable.

TERRACE SOILS

There are five terrace soils in the county classified in the Fargo, Waukesha, O'Neill, Judson and Sioux series. Together they cover 3.2 percent of the total area of the county.

FARGO SILTY CLAY LOAM (109)

The Fargo silty clay loam is the most extensive terrace type in the county, covering 1.7 percent of the total area. It occurs in numerous areas thruout the central portion of the county. The largest development of the type is in Dale Township, but there are many small individual areas of the soil in practically all parts of the county.

The surface soil of the Fargo silty clay loam is a black silty clay loam extending to a depth of 14 inches. The subsoil is a light to dark grayish-brown, heavy, moderately plastic silty clay loam to silty clay. At 26 to 30 inches, there are mottlings of yellow, brown, gray and rusty brown. The subsoil is high in lime content and frequently the lime extends thruout the soil section occurring also in the surface soil.

In topography the Fargo silty clay loam is generally flat. In depressed areas it is gently sloping. It occurs in three distinct drainage positions; first, in depressed areas in the uplands at the heads of drainageways or as low flat divides between drainageways; second, on gentle slopes adjacent to the broader and shallower upland drains; third, in real terrace positions, intermediate between the bottomlands and the uplands. The natural drainage of the type is quite inadequate in all its areas, due to the level to flat or depressed topographic position and also to the heavy texture of the soil and subsoil.

About half of the Fargo silty clay loam is in pasture, the remainder being in cultivated hay, wild hay and grain crops. Wild prairie grass and bluegrass still grow on some of the areas which are permanently wet. Only a small portion of the type is in cultivated crops. On these areas corn and oats are grown. Corn yields from 25 to 60 bushels per acre, averaging about 40 bushels. Oats yield 20 to 45 bushels, averaging about 35 bushels per acre. There is a tendency for the oats to make a rank growth and lodge, particularly in wet seasons. Timothy and clover make up the leading hay crop and yields amount to 2¼ to 2½ tons per acre. The yield of timothy alone amounts to 2 tons per acre and wild hay yields 1½ to 2 tons. Minor crops grown on the type include millet, rape, sudan grass and sorghum.

When thoro drainage is provided for this type, crop yields are quite satisfactory. The installation of tile is very necessary on many areas. Proper cultivation is essential as the soil tends to clod and bake if plowed or cultivated when too wet. Small applications of farm manure would be of value on this soil when it is newly drained but manure should not be applied preceding the growth of small grain crops. The type is usually basic in reaction and not in need of lime. If the surface soil is acid, however, applications of lime might be necessary for the best early growth of legumes. The content of phosphorus is low and the application of a phosphate fertilizer would undoubtedly prove of value. Tests of acid phosphate and rock phosphate on the soil are recommended.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the second largest terrace type in the county, covering 0.6 percent of the total area. It occurs in small areas on the terraces along practically all of the main drainageways of the county except the Ocheyedan and the Little Sioux Rivers. The largest area of the type is found in Union Township just east of Paullina. The remaining areas of the type are all small in area and rather unimportant.

The surface soil of the Waukesha silt loam is a dark brown to black silt loam containing small amounts of fine sand and very fine sand. The subsoil at 14 inches is a lighter brown, yellowish-brown or pale yellow clay loam to silty clay loam, containing somewhat larger amounts of fine sand than are present in the surface soil. At the lower depths, the subsoil is more compact and only moderately plastic. In some areas, the subsoil, at a depth of 32 to 34 inches, is a loose structured coarse sandy loam or gravelly loam. Where this variation occurs the soil is really an O'Neill loam, but in many places the areas were too small to separate out and they are included with the Waukesha silt loam. In these areas the surface soil usually approaches a heavy loam. These variations in the typical soil are found developed on the terraces along the upper courses of Waterman Creek and Little Waterman Creek. Included with the Waukesha silt loam there are also small areas of Fargo silt loam and silty clay loam which are too small to show on the map. These spots occur generally in the lowest lying and most poorly drained terraces or in poorly drained areas at the foot of upland slopes. Along the lower course of Waterman Creek there is considerable variation in the character of the surface soil material due to wash from the slopes above.

In the deeper valleys, the Waukesha silt loam on the terraces lies 15 to 30 feet above the bottoms. Along the smaller streams, however, the soil is only 5 to 10 feet above the first bottoms. In the large area near Paullina, the soil is 15 to 20 feet above the adjacent stream. In topography, the type is level to gently undulating. Natural drainage of the soil is usually quite adequate. In the areas where the subsoil rests on a loose gravel substratum, the drainage of the soil is better.

The Waukesha silt loam is very largely cultivated, the chief crops grown being corn, oats and barley. There is a considerable acreage in hay which consists of timothy and red clover and small areas of alfalfa. Some of the soil is used for pasture purposes. Small areas of the type adjacent to the bottomland are usually utilized in this way.

On the cultivated areas, the yields of general farm crops are very much the same as those secured on the Marshall silt loam on the upland. The soil treatments which will bring about increased crop yields are very similar to those suggested for the Marshall silt loam. The application of farm manure is of very large value on the soil and will bring about large increases in crop yields. The type is acid in reaction and applications of lime are very necessary for the best growth of general farm crops, particularly of legumes. The application of a phosphate fertilizer would undoubtedly prove of value and tests of acid phos-

phate and rock phosphate are recommended. Experiments reported earlier have shown very large effects of applications of manure, lime and phosphorus to this soil.

O'NEILL LOAM (108)

The O'Neill loam is a minor terrace type in the county covering only 0.4 percent of the total area. It occurs in several small areas on the terraces along the Ocheyedan River, the Little Sioux River and the lower courses of Waterman and Mill Creeks. The largest area of the type is found along the Ocheyedan River in Hartley Township in the northeast corner of the county. The other areas of the type are very small in extent and relatively unimportant.

The surface soil of the O'Neill loam is a dark brown to black heavy loam, extending to a depth of 10 to 12 inches. The subsoil at a depth of 20 inches is a yellowish-brown heavy loam to clay loam, in places moderately compact. Below this, the subsoil is a yellowish-brown to brownish-yellow sandy loam to coarse sandy loam or gravelly loam, with a loose porous structure and layers of sand and gravel. In some areas the layer of heavier material is thicker than 20 inches but in most cases the gravelly sandy subsoil is reached at shallower depths and may appear at 10 inches below the surface. In places the subsoil is a very loose sand and gravel.

The O'Neill loam occurs on terraces usually about 25 feet above the bottoms. There is considerable variation, however. In section 24 of Waterman township, it occurs on the terrace 50 feet above the river bottom, while in section 29 of Omega Township the type is only five to eight feet above the bottoms. In topography, the soil is level, drainage is adequate and in dry seasons crops are apt to suffer from drouth.

About half of the O'Neill loam is in pasture and hay land, the remainder being cultivated. Corn is grown to a large extent on the cultivated areas, yielding 30 bushels per acre. Oats yield 25 to 30 bushels and timothy and clover hay 1 to 1½ tons per acre. Crop yields are extremely variable depending upon the seasonal conditions. In dry years the yields are very low while in wet seasons or seasons of normal rainfall, the yields may be quite satisfactory.

This type is particularly in need of organic matter in which it is low and applications of farm manure are very desirable. Turning under leguminous crops as green manures would also be of considerable help. The liberal use of organic matter on this type will reduce the danger of injury from drouth. The type is acid in reaction and applications of lime are necessary especially before legumes are grown. The phosphorus content is low and the use of a phosphate fertilizer would undoubtedly prove of value. Tests of acid phosphate are recommended.

JUDSON LOAM (190)

The Judson loam is a minor type in the county, covering only 0.3 percent of the total area. It occurs in several small areas in Grant and Waterman Townships, along the Little Sioux River and Waterman Creek. The largest area of the type is along the Little Sioux River in the southeast corner of the county.

The surface soil of the Judson loam is a dark brown to almost black mellow loam to heavy loam, extending to a depth of 10 inches. Below that point it grades into a dark brown to black material of the same texture, slightly more compact than the surface soil. At 20 inches, the subsoil is a dark brown, moderately plastic loam, containing a little more fine sand than the surface material. The type is rather variable in characteristics, the surface soil ranging from a fine sandy loam to a heavy loam, and is subject to considerable change in texture depending upon the washing of the material from the upper slopes. Thin layers of loose sand are occasionally encountered in the subsoil. Small areas

of Sioux loam and O'Neill loam are included with the type as they are too small to separate on the map. In a few places small quantities of lime occur in the lower subsoil.

The Judson loam is developed typically at the base of the steep upland areas bordering the valleys. Narrow strips occur along the higher bluffs, and are more or less modified in characteristics by the material washed down from above. In a few areas the type occurs in a typical terrace position. In topography, it is gently sloping to very gently sloping in slope-wash positions, while it is level to undulating in the terrace position. Drainage of the type is usually quite adequate.

Most of the Judson loam is cultivated, corn being the chief crop grown. The yields of the crop amount to 50 to 60 bushels per acre. Small grains are grown to some extent but they tend to lodge. Some of the type is in grass but very little of it is used for pasture.

Crop yields on the Judson silt loam are very much the same as those secured on the Marshall silt loam on the upland, and the treatments needed to make the soil more productive are likewise very similar. It will respond to applications of farm manure, it is acid in reaction and additions of lime are desirable and the use of a phosphate fertilizer will undoubtedly prove of value. Tests of the effect of acid phosphate on this soil are recommended.

SIOUX LOAM (76)

The Sioux loam is a minor type in the county, covering only 0.2 percent of the total area. It occurs in several small areas in Grant and Waterman Townships on the terraces adjacent to Waterman Creek and the Little Sioux River. There are no large areas of the type.

The surface soil of the Sioux loam is a dark brown to black mellow loam to heavy loam. The subsoil at 10 to 12 inches is a light yellowish-brown or grayish-yellow loam to fine sandy loam or sandy loam, loose in structure and containing some lime. At 20 inches the sand becomes coarser and the subsoil has a loose porous structure, the texture varying from a fairly uniform fine sandy loam to a sandy or gravelly loam. Lime is generally present thruout the subsurface soil and the subsoil. In topography, the Sioux loam is level and drainage is adequate to excessive. The type is apt to prove drouthy in dry seasons. The soil occurs on terraces about the same distance above the bottoms as was noted in the case of the O'Neill loam.

About three-fourths of the type is utilized for hay and pasture land, the remainder being cropped. The crops grown and the yields are very much the same as those secured on the O'Neill loam. In favorable seasons, the yields of corn and small grains may be quite satisfactory but in dry seasons the yields are poor.

The type needs chiefly the incorporation of organic matter in order to make it more retentive of moisture and less subject to injury by drouth. Liberal applications of farm manure are desirable and leguminous crops should be utilized as green manures in order to increase the content of organic matter. The type is high in lime content thruout the subsurface and subsoil and probably is rarely in need of lime. If the surface soil is acid, however, and legumes are to be grown, it might be desirable to make an application of lime to stimulate the early growth of the crops. The content of phosphorus is low and applications of a phosphate fertilizer would undoubtedly prove of value for general farm crops.

SWAMP AND BOTTOMLAND SOILS

There are four swamp and bottomland soils in the county, classified in the Lamoure and Wabash series. Together they cover 7.3 percent of the total area of the county.

LAMOURE SILTY CLAY LOAM (111)

The Lamoure silty clay loam is the most extensive bottomland soil in the county and the third largest type, covering 4.6 percent of the total area. It occurs in numerous areas along the various rivers and streams of the county. The largest development of the type is in Hartley Township in the northeastern corner along the Ocheyedan River. Another extensive development of the type is in Floyd Township along the Floyd River. The remainder of the areas of the soil are small and relatively unimportant usually being narrow and irregular in shape, and occurring along the tributary streams and intermittent drainageways which extend thruout the upland in the central portion of the county.

The surface soil of the Lamoure silty clay loam is an almost black moderately plastic to plastic silty clay loam to silty clay high in organic matter. At 16 to 18 inches, the subsoil is a dark brown to black plastic silty clay. In the lower subsoil there are mottlings of yellow, brown and gray. The subsoil is highly calcareous, and the surface soil frequently shows a large content of lime. In some places at depths of 24 to 36 inches there is some coarse sand and gravel. This is true of much of the area along the Ocheyedan River and in those areas along the upper course of Waterman Creek in Lincoln Township. In these areas the sandy and gravelly material appears only in spots in the subsoil, but occurs rather generally at depths of 5 to 10 feet. There is some variation in the texture of the surface soil when the type occurs adjacent to other bottomlands or in narrow upland swales and the texture may approach a loam or a silty clay. The boundaries between the type and the Lamoure loam are frequently established rather arbitrarily.

In topography, the Lamoure silty clay loam is level to depressed. In the larger occurrences, the surface is cut only by old stream channels. In the narrow areas of the type, it occurs in narrow valleys and depressed upland swales or former pond areas. The natural drainage of the type is poor. The soil is subject to frequent overflow and, due to this fact and the heavy character of the subsoil as well as the surface soil, the type is almost continuously water logged. Along the Ocheyedan River valley, the stream channel has been dredged and straightened to prevent overflow and here crops are grown quite successfully. In other areas crop yields are quite uncertain.

About 65 to 70 percent of the type is in pasture land. Tame hay and wild hay occupy 20 to 25 percent and the remainder is in grain crops. Where the land has been drained and protected from overflow crop yields are quite satisfactory. Corn is grown to the greatest extent and yields 45 to 55 bushels per acre. Oats yield 25 to 35 bushels per acre; timothy and clover, 2¼ to 2½ tons; timothy alone, 2 tons per acre. Wild grasses yield about 1½ to 2 tons of hay per acre. Oats and small grain crops frequently prove unsatisfactory because of the tendency to lodge.

The chief need of the Lamoure silty clay loam to make it more productive is the installation of adequate drainage and the protection from overflow. Tiling will be very desirable in many cases after the type has been protected from flood waters. When thoro drainage is accomplished, small amounts of farm manure would be of value in stimulating the production of available plant food. Large amounts of manure should not be applied and no manure should be applied preceding the growth of the small grain crop because of its tendency to increase the danger of lodging. The type is basic in reaction and not in need of additions of lime. The content of phosphorus is not high and additions of a phosphate fertilizer would undoubtedly prove of value. Field experiments with this soil have indicated the effectiveness of small amounts of manure in increasing the yields of general farm crops and have shown also the value of applications of a phosphate fertilizer. Acid phosphate seems to be somewhat preferable for use but rock phosphate sometimes gives quite as desirable effects. Tests of both acid phosphate and rock phosphate are recommended on the soil.

LAMOURE LOAM (112)

The Lamoure loam is the second largest bottomland soil in the county, covering 1.3 percent of the total area. It occurs in numerous narrow, irregular-shaped areas chiefly along Waterman Creek, Willow Creek, Floyd River and Little Floyd River. There are small areas of the type along Mill Creek and some of the other streams in the county. No large individual areas of the soil occur.

The surface soil of the Lamoure loam is a dark brown to black light to heavy mellow loam, containing considerable fine sand. At 16 inches the subsoil is a dark grayish-brown to black heavy loam to light silt loam, containing some sand. Calcareous material occurs in abundance thruout the soil section. There are numerous variations in the character of this soil. In the valley of Waterman Creek in Omega, Grant and Waterman Townships the surface texture varies from a fine sandy loam to a heavy loam. Occasionally layers of loose sand are found at varying depths. The deeper subsoil material is sometimes a heavy plastic silt loam to silty clay loam. This is true in sections 25 to 36 of Union Township and along the lower course of the Floyd River. Another variation of the type occurs where there has been considerable wash from the slope over the bottomlands. This variation from the typical soil is evidenced particularly along Waterman Creek. In topography, the Lamoure loam is level and the type is fairly well drained. It is subject to overflow, however, and if it is to be utilized for cultivated crops it must be protected from flood waters.

Included with the Lamoure loam are several small areas of the Lamoure silt loam which were too small to show on the map. In these areas the surface soil is an almost black light to heavy silt loam 14 to 16 inches in depth. The subsoil is a dark brown to black heavy clay loam, extending to a depth of 24 inches where it grades into a dark grayish-brown to black heavy plastic silty clay loam to silty clay, mottled with yellow, brown and gray. The subsoil is highly calcareous and the surface soil is usually high in lime also. This variation from the typical soil is found developed in Grant Township along the Jordan Creek and in Hartley Township along Waterman Creek. There is also an area in section 20 of Union Township.

The Lamoure loam is utilized chiefly for pasture and hay lands, very little of the type being in cultivated crops. Corn is the principal crop grown on the cultivated areas. The crop yields are very much the same as those secured on the Wabash loam.

The chief need of the Lamoure loam is for protection from overflow and for adequate drainage. When these are accomplished, very satisfactory crop yields may be secured. In cultivated areas, applications of farm manure would be very desirable following drainage in order to stimulate the production of available plant food. Small amounts of manure may be used with large value on general farm crops. Manure should not be applied, however, preceding the growth of a small grain crop owing to the danger of causing the crop to lodge. The type is low in phosphorus and applications of a phosphate fertilizer would undoubtedly be of value. Tests of acid phosphate are recommended.

WABASH LOAM (49)

The Wabash loam is a minor type in the county, covering only 1.1 percent of the total area. It is developed in narrow, irregular strips of bottomland along Mill Creek to the fork of Dry Run in Dale Township, along the Little Sioux River and the lower course of Waterman Creek in Waterman Township. It occurs also in small areas along some of the tributary streams to Mill Creek and in other areas along Waterman Creek.

The surface soil of the Wabash loam is a dark brown to black light to heavy mellow loam, containing some sand. Below 14 inches the material is somewhat

more compact and in places somewhat heavier in texture. At the lower depths the material is slightly lighter in color and the lower subsoil locally contains mottlings of yellowish-brown and rusty brown. There are some variations from the typical soil. Shallow layers of loose fine sand to sandy loam are occasionally found thruout the soil section. The texture of the surface soil may vary from a light sandy loam to a heavy loam. In the more extensive areas the surface soil, in places, approaches a silt loam. The subsoil is heavier in texture, more compact in structure and shows more mottling with yellowish-brown and rusty brown. Within the type are areas of Lamoure soils which are too small to show separately on the map. On the broader bottomland, the soil is more uniform and typical while the greatest variations occur in the narrow valleys along the swifter streams.

In topography, the Wabash loam is level. Natural drainage is good. The type is subject to overflow, however, and if it is to be utilized for cultivated crops it must be protected from flood waters.

The Wabash loam is chiefly utilized as pasture land. Higher areas along the Little Sioux River and Mill Creek are cropped, chiefly to corn. Small grain and tame hay are grown to some extent. Corn yields 45 to 60 bushels per acre; oats, 25 to 40 bushels; timothy alone, 1½ to 2 tons; and timothy and clover mixed, about 2 to 2½ tons of hay per acre. Bluegrass is the chief permanent pasture grass. Prairie or slough grasses make a good growth and provide both hay and pasturage.

When the type has been protected from overflow and adequate drainage has been provided, general farm crops may be very successfully grown. The chief needs of the soil after drainage and overflow have been provided, are for the incorporation of some organic matter, the application of lime if the type is acid, and the use of a phosphate fertilizer.

WABASH SILT LOAM (26)

The Wabash silt loam is a minor bottomland type in the county, covering only 0.3 percent of the total area. It is found in several small narrow irregular-shaped areas along the streams of the county. The chief development is along Ocheyedan River in the northeastern corner of the county and along the Little Sioux River in the southeastern corner. Other small areas of the type are found along Waterman Creek and along some of the other streams of the county.

The surface soil of the Wabash silt loam is a dark brown to almost black light to heavy silt loam, extending to a depth of 10 inches. Below that point it becomes a dark grayish-brown heavy loam to light silt loam containing considerable amounts of fine sand. Below 16 to 18 inches the subsoil is a dark brown to black rather plastic heavy silt loam to light silty clay loam. In the lower subsoil faint mottlings of yellowish-brown and rusty brown occur. In the areas where drainage has been poorest the lower subsoil is yellowish-brown, gray and rusty brown and the texture is a silty clay loam to silty clay. This is the typical subsoil character of the type along the Ocheyedan River. There are variable amounts of sand present thruout the soil in various locations. Where the type is adjacent to the Judson silt loam, the surface soil has been modified by some slope wash material. The boundaries between the two types are established rather arbitrarily.

In topography, the Wabash silt loam is level. Natural drainage is fairly well developed but artificial drainage is necessary for the best crop growth. The type is generally subject to overflow.

Several small areas of Wabash silty clay loam are included with the Wabash silt loam because of their small extent. In these areas the surface soil is an almost black silty clay loam, extending to a depth of 16 to 18 inches. Below that point, the subsoil is a heavy poorly oxidized silty clay loam to silty clay, dark brown to black in color with stains of yellowish-brown, gray and rusty

brown. The chief areas of this modification of the type are in section 33 of Dale Township, sections 25 and 36 of Hartley Township, in Omega Township along Little Waterman Creek and in Caledonia Township along Deep Creek. The topography is flat and depressed and natural drainage is poor. These areas are best suited for pasture.

The greater part of the Wabash silt loam is utilized for pasture. On cultivated areas, however, crop yields are generally quite satisfactory. Corn yields 50 to 55 bushels and oats, 25 to 35 bushels. Hay yields are very much the same as those secured on the Wabash loam. When the type is protected from overflow and adequate drainage is assured, satisfactory crop yields are usually secured. The type is chiefly in need of lime for the best growth of legumes and small amounts of farm manure would be of value on newly drained areas to stimulate the production of available plant food and tests of a phosphate fertilizer are desirable.

APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

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

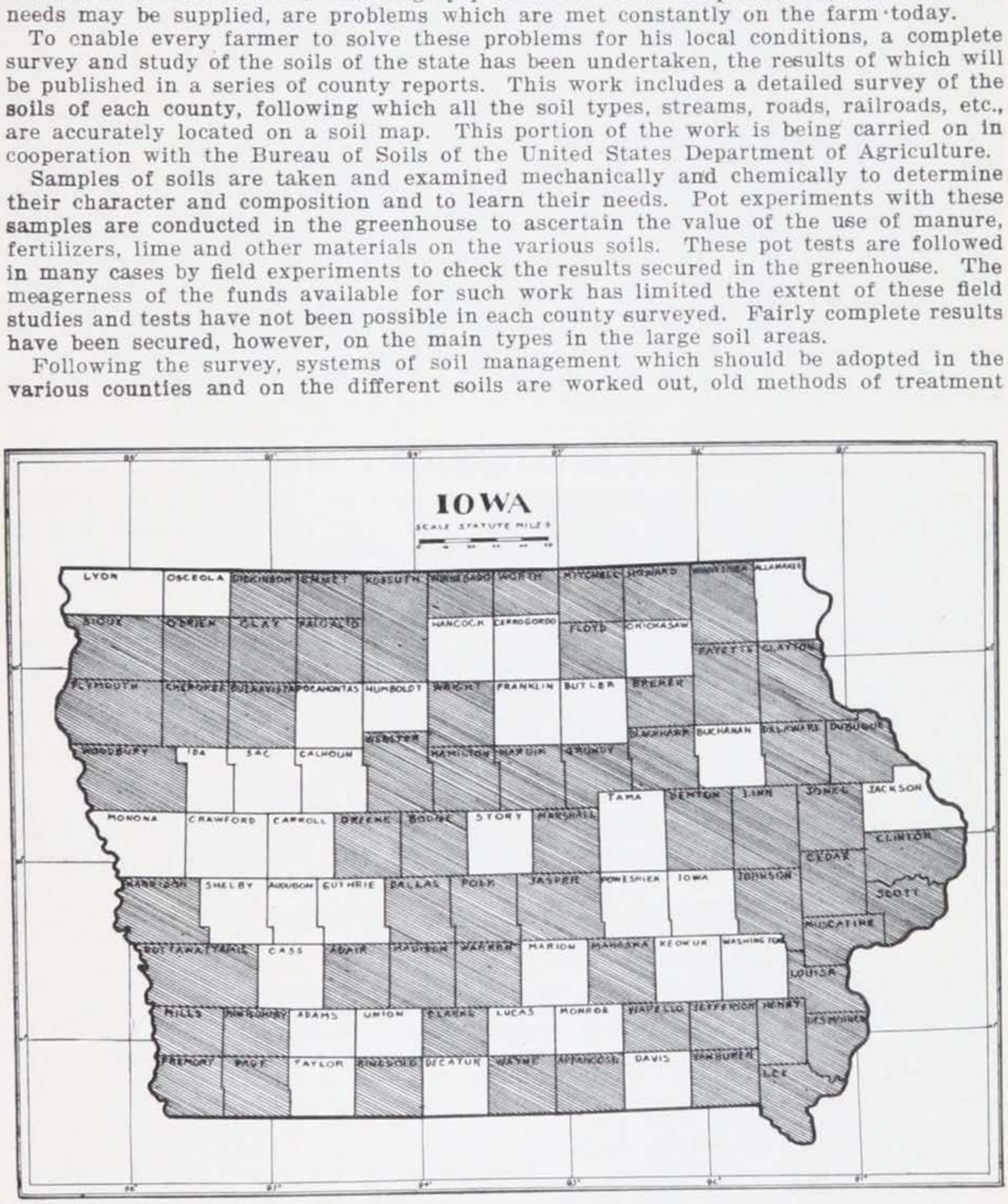

Fig. 11. Map of Iowa showing the counties surveyed.

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

PLANT FOOD IN SOILS

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

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmopshere 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 method carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

AVAILABLE AND UNAVAILABLE PLANT FOOD

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

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavailable.* Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion, but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available 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 acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

TABLE I. PLANT FOOD IN CROPS AND VALUE

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

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25T.	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

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

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

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

REMOVAL FROM IOWA SOIL

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

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

CULTIVATION AND DRAINAGE

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

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

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

THE ROTATION OF CROPS

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

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

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

MANURING

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

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

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

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

THE USE OF PHOSPHORUS

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

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

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

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occuring 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. 12.

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

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

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

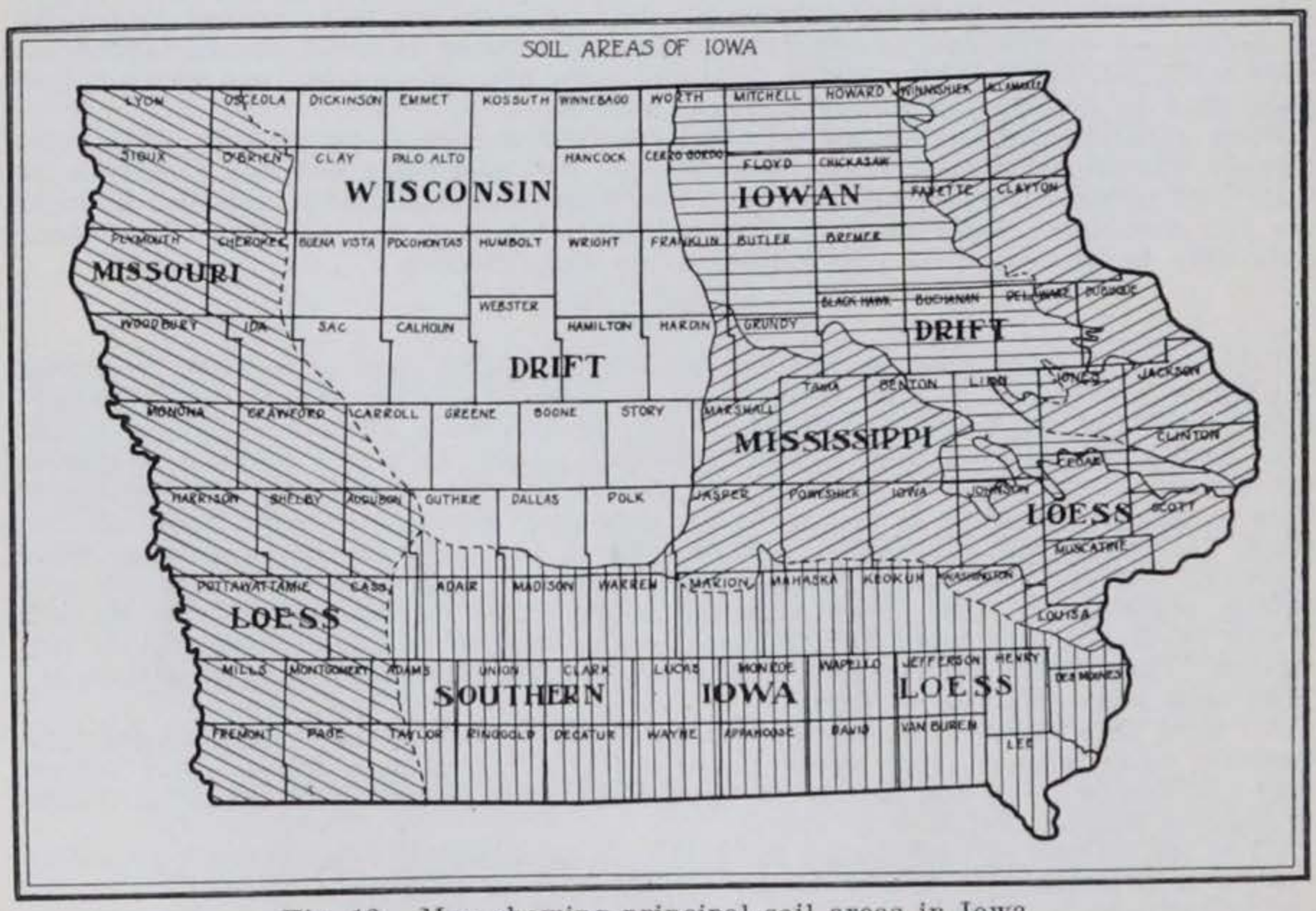

Fig. 12. Map showing principal soil areas in Iowa.

THE SOIL SURVEY BY COUNTIES

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

This is what is accomplished by the soil survey of the state by counties, and hence 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 of the soil type.

GENERAL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into soil survey work from this source is very small and need cause iittle 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 undecomposed vegetable and animal material.
Inorganic matter	Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Gravels—More than 50 percent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

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

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

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

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by 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 determination 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.