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# SOIL SURVEY OF IOWA
## HARRISON COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

**Agronomy Section**

**Soils**



**Soil Survey Report No. 55**

**May, 1929**

**Ames, Iowa**

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May, 1929 Soil Survey Report No. 55

# SOIL SURVEY OF IOWA

## Report No. 55—HARRISON COUNTY SOILS

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



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

## CONTENTS

# HARRISON COUNTY SOILS*

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

Harrison County is located in southwestern Iowa, being separated by the Missouri River from Nebraska on the west and in the fourth tier of counties north of the Missouri state line. It lies entirely in the Missouri loess soil area and the soils of the county are, therefore, mainly of loessial origin.

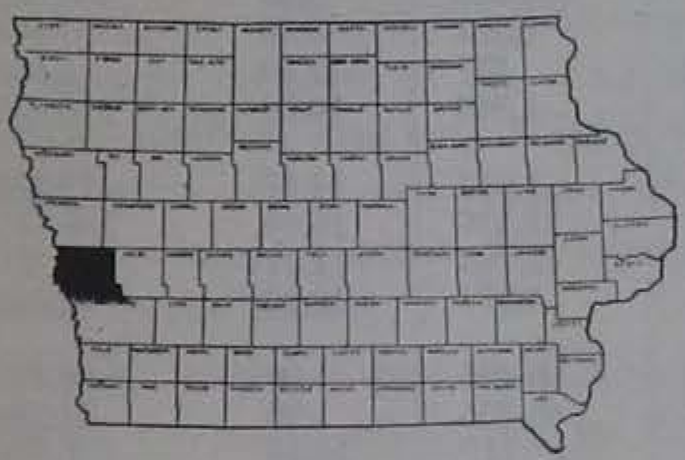


Fig. 1. Map showing location of Harrison County.

The total area of the county is 691 square miles or 442,240 acres. Of this area 417,056 acres, or 94.3 percent, are in farm land. The total number of farms is 2,709 and the average size of the farms is 154 acres; 41.2 percent of the total farm land is operated by owners, while the remaining 58.8 percent is operated by renters. The following figures taken from the Iowa Yearbook of Agriculture for 1927 show the utilization of the farm land in the county:

| | |
|---|---|
| Acreage in general farm crops | 266,127 |
| Acreage in farm buildings, public highways and feed lots | 18,454 |
| Acreage in pasture | 102,946 |
| Acreage in waste land not utilized for any purpose | 9,474 |
| Acreage in farm woodlots used for timber only | 3,182 |
| Acreage in farm lands lying idle | 5,672 |
| Acreage in crops not otherwise listed | 673 |

## THE TYPE OF AGRICULTURE IN HARRISON COUNTY

The type of agriculture practiced in Harrison County at the present time consists mainly of a system of general farming, including the production of grain and hay and the raising and feeding of livestock. Dairying is carried on to some extent, and in some sections fruit growing is practiced rather extensively. The chief crops are corn, oats, wheat, barley, alfalfa and sweet clover. Wheat is the principal cash crop, altho in recent years considerable amounts of corn have been shipped out of the county and marketed in Omaha and Council Bluffs. The remainder of the general farm crops are utilized practically entirely for feeding purposes.

The chief sources of income in the county are from the sale of hogs, beef cattle, dairy cattle, sheep and horses and from the sale of wheat and corn. Hog raising is the most extensive livestock industry and probably provides the largest single source of income on the farms. In the sections where fruit growing is practiced, considerable income is derived from the sale of the fruit produced. On individual farms some income comes from the sale of potatoes, truck crops, small fruits and other minor crops.

There is a considerable area of waste land, much of which might be reclaimed and made productive if proper methods of soil treatment were adopted. It is impossible to give general recommendations for the reclamation of infertile

*See soil survey of Harrison County, Iowa, by T. H. Benton, of the Iowa Agricultural Experiment Station, in charge, and N. J. Russell, of the U. S. Department of Agriculture. Field operations of the Bureau of Soils, 1923.

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

| Crop | Acreage | Percent of total farm land of county | Bushels or tons per acre | Total bushels or tons | Average price | Total value of crops |
|---|---|---|---|---|---|---|
| Corn | 182,644 | 43.8 | 40.4 | 7,378,818 | $0.69 | $5,091,384 |
| Oats | 58,281 | 13.9 | 30.2 | 1,761,135 | 0.42 | 739,677 |
| Winter wheat | 117 | 0.03 | 17.5 | 2,050 | 1.17 | 2,399 |
| Spring wheat | 58 | 0.01 | 11.0 | 638 | 1.15 | 734 |
| Barley | 5,161 | 1.2 | 32.0 | 164,942 | 0.66 | 108,862 |
| Rye | 83 | 0.02 | 16.3 | 1,353 | 0.86 | 1,164 |
| Clover hay | 239 | 0.06 | 1.87 | 447 | 12.50 | 5,588 |
| Timothy hay | 1,081 | 0.26 | 1.43 | 1,546 | 10.50 | 16,233 |
| Clover and timothy hay (mixed) | 632 | 0.15 | 1.65 | 1,043 | 11.77 | 12,276 |
| Alfalfa | 9,015 | 2.1 | 2.40 | 21,636 | 16.00 | 346,176 |
| All other tame hay | 4,579 | 1.1 | 3.01 | 13,783 | 11.77 | 162,226 |
| Wild hay | 3,618 | 0.86 | 1.43 | 5,174 | 10.00 | 51,740 |
| Soybeans | 67 | 0.01 | ------ | -------- | ------ | ---------- |
| Potatoes | 535 | 0.12 | 57.0 | 30,495 | 1.00 | 30,495 |
| Apples | ------ | ------- | ------ | 40,666 | 1.95 | 79,299 |
| Clover seed | 45 | 0.01 | 2.49 | 112 | 16.10 | 1,803 |
| Sweet clover seed | 2,063 | 0.49 | 4.60 | 9,420 | 5.50 | 51,810 |
| Sweet clover (all purposes) | 11,759 | 2.8 | ------ | -------- | ------ | ---------- |

*Iowa Yearbook of Agriculture, 1927.

areas, inasmuch as the causes for the lack of good crop production are various. Later in this report, suggestions will be offered for the treatment of individual areas of waste land. In special cases, where the conditions are more or less abnormal, advice regarding the handling of these areas will be given by the Soils Section of the Iowa Agricultural Experiment Station, upon request.

## THE GENERAL FARM CROPS GROWN IN HARRISON COUNTY

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

The leading crop, both in acreage and value, is corn. In 1927, it was grown on 43.8 percent of the total farm land and average yields amounted to 40.4 bushels per acre. The most popular varieties are Reid Yellow Dent and Iowa Silver Mine. The yields vary considerably, depending upon the soil type characteristics and the fertility of the soil. In many cases where corn is grown following sweet clover and alfalfa, the yields range quite regularly from 50 to 55 bushels per acre. In some cases yields may be increased to an even greater extent thru the proper handling of the soil. In recent years a considerable quantity of the corn produced has been shipped out of the county and marketed on the Omaha and Council Bluffs markets. The major portion of the crop, however, is utilized for feed on the farms.

The second crop in importance is oats. In 1927 this crop was grown on 13.9 percent of the total farm land, and average yields amounted to 30.2 bushels per acre. Iowa 103, Iowa 105, Iowar, Kherson and Green Russian are the varieties most commonly grown. These varieties are listed in the order of their importance. Practically all of the oats crop produced is utilized on the farms for feeding purposes.

Alfalfa is the third crop in value and it is grown extensively both on the upland and bottomland soils. In 1927 it was produced on 2.1 percent of the total farm land and yields amounted to 2.4 tons per acre. Under the most favorable conditions the yields range as high as 4 tons per acre. Two or three cuttings are usually made during the season. The Grimm and Turkestan varieties are most commonly grown. Most of the seed comes from North Dakota and a little from Nebraska. Most of the alfalfa crop is fed on the farms, either as hay or pasture. In 1923 it was estimated that about 50 carloads were baled and shipped annually to neighboring counties and to the east. Good yields of alfalfa may be secured on most of the land throughout this county provided that the land is well drained and any acidity of the soil is neutralized before seeding. The inoculation of the crop is also of value if it has not been grown previously on the same land or sweet clover has not been produced. Alfalfa is a crop of large value in the county.

Sweet clover is grown extensively. In 1927 it is estimated that sweet clover for all purposes was grown on 2.8 percent of the total farm land. Most of the sweet clover produced is of the biennial varieties. The seed comes mainly from Nebraska and the Dakotas. The crop serves chiefly for pasture purposes and for green manuring. Sweet clover is grown for seed on a limited area but most of the crop is used for feeding purposes, none being sold on the market. Yellow sweet clover is grown somewhat more generally than the white clover, and this crop serves preferably for seed. The white sweet clover is considered somewhat better for green manuring. Sweet clover makes an excellent green manure crop if properly plowed under and may bring about considerable increases in the yields of subsequent grain crops.

Barley is grown on limited areas. In 1927, 1.2 percent of the farm land was utilized for this crop. Average yields amounted to 32 bushels per acre. The value of the crop is considerable. It is all utilized on the farms.

The hay crops, in addition to the alfalfa and sweet clover which have been mentioned, include red clover, which is grown on a very limited area and timothy and some clover and timothy mixed. A small area is in wild hay. This crop is chiefly taken from the low, poorly drained bottomlands. Practically all of the hay produced, with the exception of some alfalfa, is fed on the farms. A very limited acreage of clover is grown for seed.

In the southeastern part of the county and on the heavier textured soils along the Missouri River, wheat is the chief cash crop. The winter varieties are grown mainly, and in 1927 the yields were estimated at 17.5 bushels per acre. The Turkey, Kanred and Kharkof are the principal varieties. There is a limited area in spring wheat, the variety grown being chiefly Marquis. The wheat crop is all sold off the farms, being shipped to the Omaha and Council Bluffs markets.

Minor farm crops include rye, emmer, buckwheat, crimson clover, Japan clover, Dalea and soybeans. Dalea is an annual legume which grows wild on the river bottoms. It makes a valuable green manure crop and is utilized to some extent for that purpose. Soybeans are grown mainly for hogging down and for silage. They are usually planted with corn by means of a special attachment to the corn planter. Manchu is the variety most commonly used for hogging down; some Midwest is grown for silage. Black Eyebrow and Ito San are other popular varieties. Sudan grass is grown locally and utilized for hay or pasture. Sorghum is produced on a small area and the syrup is disposed of on the local markets. There are few bluegrass pastures in the county.

Potatoes are grown extensively and the crop is of considerable money value. The average yield in 1927 was 57 bushels per acre. Very much larger yields than this are secured with proper methods of soil treatment and fertilization. The varieties are chiefly Early Ohio, and to a lesser extent the Rural New Yorker and Irish Cobbler. From 15 to 20 carloads are shipped in some seasons, chiefly to the commission houses in Omaha.

Onions are raised on a commercial basis in the area south of Modale in Clay and Cincinnati townships. They are marketed chiefly in Omaha. Melons are grown in some areas for the local markets and some are shipped out of the county. The melons are produced chiefly on the sandy bottomlands on the outer edge of the Missouri bottoms. Other truck crops and vegetables are grown and sold on the local markets.

Fruit growing is rather extensively developed in some parts of the county, the chief sections being in Raglan Township, and to a lesser extent in St. John and Boyer Townships. Apples are the fruit grown most generally but there are some cherries, plums and a few peaches and apricots. Jonathan is the most popular variety of apples although there are some Grimes Golden, Winesap, Delicious, York Imperial, Gano, Ben Davis, Northwestern Greening, Wealthy and Willow Twig. From 50 to 70 carloads of apples are shipped out in the average season, and the income from the sale of this crop is considerable on some farms.

Some grapes are grown and sold on the local markets. Raspberries, blackberries and strawberries are grown to some extent and sold on the local markets or in the neighboring counties.

## THE HARRISON COUNTY LIVESTOCK INDUSTRY

The livestock industry of the county includes the raising and feeding of hogs, beef cattle, dairy cattle, sheep and horses.

The following figures taken from the Iowa Monthly Crop Report for July 1, 1928, giving the January 1, 1928, estimates of the Bureau of Agricultural Economics of the U. S. Department of Agriculture, in cooperation with the Iowa State Department of Agriculture, show the extent of the livestock industry:

| | |
|---|---|
| Horses | 13,300 |
| Mules | 3,090 |
| Cattle, all | 33,700 |
| Hogs | 135,600 |
| Sheep | 5,800 |

The raising and feeding of hogs is by far the most extensive livestock industry. Most of the hogs are grades but there are a few purebred herds of Duroc Jersey, Hampshire, Poland China, Chester White and Spotted Poland China. Hogs are shipped in annually from Kansas City and Omaha, fattened on the farms and sold later on the Omaha, Chicago or Sioux City markets. Hogs are marketed thru cooperative shipping associations and thru local buyers, altho some large feeders ship direct to the packing houses.

Beef cattle are second in importance to hogs. The breeds are chiefly Shorthorn grades, with some Hereford and Angus. There are a few purebred herds, chiefly Hereford and Shorthorn. About 250 carloads of western feeders are shipped in annually and fed on the farms. Over 60 percent of the finished cattle are marketed in Omaha and the remainder largely in Chicago.

Dairying is practiced to some extent and there are a number of commercial dairy herds. The Holstein, Guernsey and Milking Shorthorn are the most popular dairy breeds. There are a few Jersey and Brown Swiss. The cream is sold at the cream buying stations in adjacent towns, from which it is shipped to Denison, Council Bluffs and Omaha.

Sheep raising is of minor importance, altho a number of small flocks, chiefly of the Shropshire breed, are found. Several carloads of western feeders are shipped in annually in October; fattened and sold later on the Omaha markets. A considerable amount of wool is clipped annually and marketed thru the Iowa Wool Growers Association.

A few horses are raised on practically all farms, but the industry is not extensively developed. There are some mules raised. A few Angora goats are kept in the rougher sections.

Poultry raising is practiced extensively thruout the county. The income from this industry on individual farms is often considerable. There are many flocks of purebred fowls. The chief breeds are the Rhode Island Red, Wyandotte, Leghorn and Barred and White Plymouth Rocks. There are some flocks of geese, ducks, turkeys and guinea fowls raised on individual farms.

Farm land in Harrison County is quite variable in price, depending upon the location with reference to towns and railroad facilities, and also with reference to the improvements on the farms and general soil conditions. Good upland farms ranged in price from $85 to $200 per acre, the year of the survey (1923). The bottomland soils varied from $25 to $200 per acre, depending mainly upon the character of the soil. The rougher upland farms sell for $30 to $50 per acre. Well improved farms adjacent to the towns may bring much higher figures.

## THE FERTILITY SITUATION IN HARRISON COUNTY

The yields of general farm crops in Harrison County are ordinarily satisfactory. Better methods of soil treatment, however, may frequently result in large crop increases. The particular treatment which should be practiced in any individual case will be determined by the character of the soil and the conditions pertaining to the area. Each of the individual soil types will be discussed separately from this standpoint later in the report. There are, however, certain general soil treatments which may be recommended for use thruout the county. They will all tend to bring about better crop yields and to permit of the maintenance of the fertility of the soils in a permanent way. They may, therefore, be mentioned here briefly.

In general the upland soils are adequately drained, but on many of the bottomlands the lack of drainage is a very great detriment to satisfactory crop growth. On the nearly level to flat areas of heavy textured soils where drainage is not provided, water may stand for long periods following rains and poor crop yields will result. Most of the bottomland areas are cut only by a few sluggish, winding streams or sloughs. The straightening and deepening of some of these shallow drainage channels has improved drainage conditions in the bottoms thruout much of the area. The installation of tile would also be of help in many of the poorly drained areas, and in a number of cases, most satisfactory crop yields cannot be secured without more thoro drainage than is being accomplished now.

While the great majority of the bottomland soils are well supplied with lime, some of the upland types, particularly the most extensively developed soils, are slightly acid in reaction. This is true in the case of the Marshall silt loam and the Carrington loam, which are the chief upland soils, and of the Waukesha silt loam and the Judson silt loam on the terraces. Wherever the soil is acid in reaction the addition of lime is very desirable for the best growth of legumes, such as sweet clover and alfalfa. It is frequently of value on the Marshall silt loam, and on the Waukesha and Judson soils on the terraces, for legume crops. On the bottomlands lime is not generally needed except on the Wabash types.

Many of the bottomland soils are very well supplied with organic matter and they show this by their black color. On the uplands and on the terraces, however, while the soils are not particularly deficient, there is no large supply of organic matter. Applications of farm manure are particularly desirable on many of these areas, and large increases in the yields of general farm crops follow the use of manure. Where farm manure is not available for application to the upland and terrace soils, the turning under of leguminous crops as green manures is recommended. Sweet clover is used largely for green manuring purposes, and other legumes such as dalea are utilized to some extent. The yields of general farm crops are materially increased where the organic matter and nitrogen supplies of the soils are increased by the turning under of leguminous crops as green manure. On some of the bottomland soils, particularly those which are more sandy in texture, farm manure is of value, and leguminous green manures should also be turned under.

In general the supply of nitrogen in the soils is not low, but additions of nitrogen-containing materials should be made regularly if the supply is to be kept up. The utilization of well inoculated legumes for green manuring purposes will aid materially in building up and keeping up the nitrogen content of the soil. The use of farm manure and the proper utilization of crop residues will also aid in preventing a deficiency in nitrogen. It is improbable that commercial nitrogenous fertilizers will be needed on these soils.

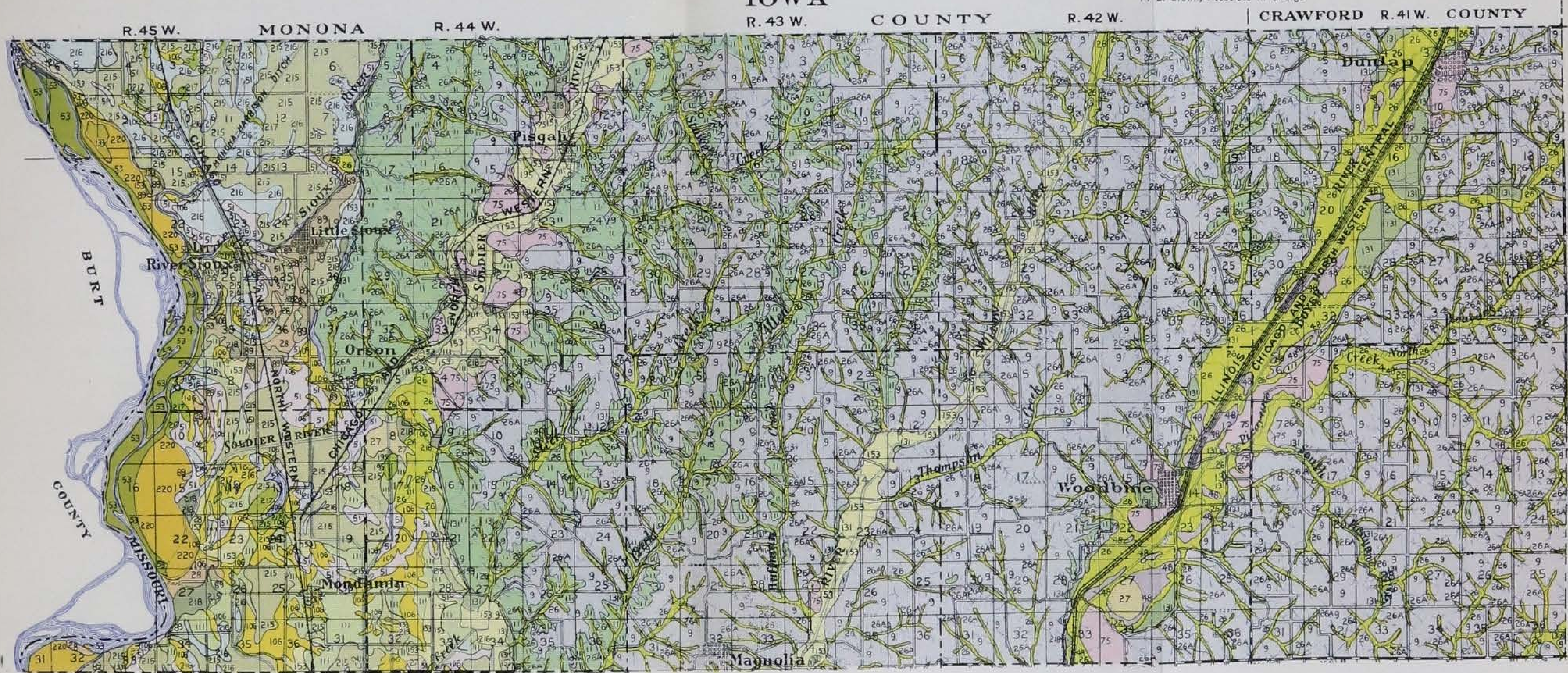
The content of phosphorus in the soils is not high and in most of the areas, it is rather low. It is evident, therefore, that phosphorus fertilizers must soon be applied if satisfactory crop yields are to be secured. Greenhouse and many field tests with phosphate fertilizers, indicate that crops may respond profitably at the present time to the use of some phosphate carrier. Either superphosphate (acid phosphate) or rock phosphate may be utilized to advantage. Altho results vary with different soil types and farm conditions, the superphosphate generally gives quicker returns and is more apt to give results on soils rather poorly supplied with organic matter. The rock phosphate may prove preferable where

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

# NORTH SECTION
# SOIL MAP OF HARRISON COUNTY IOWA

U. S. DEPT. OF AGRICULTURE, BUREAU OF CHEMISTRY AND SOILS
Henry G. Knight, Chief. A. G. McCALL, Chief, Soil Investigations
Curtis F. Marbut, in charge Soil Survey

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




## LEGEND

*Loess Soils*

- 9 — Marshall silt loam
- 11 — Knox silt loam

*Drift Soil*

- 1 — Carrington loam

*Terrace Soils*

- 75 — Waukesha silt loam
- 131 — Judson silt loam
- 214 — Hancock fine sandy loam

*Swamp and Bottomland Soils*

- 153 — Lamoure silt loam
- 215 — Lamoure silty clay
- 111 — Lamoure silty clay loam
- 26 — Wabash silt loam
- 26A — Wabash silt loam (Colluvial phase)
- 48 — Wabash silty clay loam
- 27 — Wabash silty clay
- 106 — Cass silt loam
- 51 — Cass silty clay loam
- 216 — Cass silty clay
- 217 — Cass very fine sandy loam
- 89 — Sarpy silt loam
- 218 — Sarpy silt loam (Deep phase)
- 219 — Sarpy silty clay loam (Deep phase)
- 220 — Sarpy silty clay
- 28 — Sarpy very fine sandy loam
- 133 — Sarpy fine sand
- 195 — Ray silt loam
- 53 — Riverwash

**SCALE: 1 INCH TO 2½ MILES**

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the soils are well supplied with organic matter. Tests on individual farms, of both phosphates are strongly recommended.

Complete commercial fertilizers are probably less desirable on general farm crops at the present time than is superphosphate. Comparative field experiments have indicated that the superphosphate is more profitable because of its lower cost. If complete commercial fertilizers are economical, there is no objection to their application. For truck crops, potatoes and other special crops, complete commercial fertilizers may be desirable; in fact large profits are frequently secured from their use.

Erosion occurs to some extent, chiefly on the rougher areas of the Knox silt loam. In fact this type is very largely eroded. In some sections of the Marshall silt loam, erosion occurs to a considerable extent and a washing away of the surface soil and the formation of gullies has occurred. In any case where erosion occurs on a farm, some method should be followed to prevent or control the destructive action. Suggestions which may be put into effect on any farm will be offered later in this report. From among the methods described, some one may be chosen which will fit in with practically any condition.

## THE GEOLOGY OF HARRISON COUNTY

The soils developed in Harrison County have been formed entirely from glacial or loessial deposits or from material washed down into the bottomlands from these upland deposits. The rocks laid down in early geological ages have been buried to a great depth by the later glacial and loessial deposits. It is not necessary, therefore, to consider the character of the bedrock in the county nor to dwell upon the geological history of the area, inasmuch as it has no agricultural significance.

Altho earlier glaciations may have occurred, the Kansan is the only one of any great importance from the standpoint of the soils formed in the county. This glacier swept across the county and upon its retreat left behind a vast deposit of debris known as glacial drift or till. This glacier undoubtedly covered the entire surface of the area and buried the native bedrock material under a thick deposit of blue clay containing numerous sand particles, pebbles and boulders. The old valleys were partly filled and the old hilltops were covered with the drift deposit. It varied widely in depth and when weathered, changed to a yellow or reddish-brown in color. The Carrington loam is the only soil type which has been derived from this Kansan drift material. Where this soil type occurs the later loessial covering has been entirely removed and the underlying drift exposed.

Following the glacial age, at some period in geological history when climatic conditions were very different than at present, there were laid down over the county, vast deposits of a silty material known as loess. It is generally assumed that this deposit was made by the wind. It consists of a grayish or pale buff, calcareous silty material. It was laid down evenly over the previous topographic features, but during the years which have elapsed since its deposition considerable erosion has occurred and the loess now varies in depth from 4 to 5 feet in thickness to more than 100 feet in other areas. There has also been considerable change due to weathering, the action of climatic agencies and the growth of plants. An accumulation of organic matter has occurred and in many areas the color of the surface soil has changed to a dark brown.

There are two soil types found on the upland, which are derived entirely from this loessial deposit. They are the Marshall silt loam and the Knox silt loam. The former occurs on the more gently rolling to rolling areas, while the Knox silt loam is found on the steep slopes and in the rougher sections. The Knox is much lighter in color and shows little or no accumulation of organic matter while the Marshall silt loam has darkened thru the accumulation of organic matter until it is characteristically a dark brown to black. In the areas of the Marshall silt loam there has been some erosion but not an excessive amount; in the Knox areas erosion has occurred to a considerable extent. On the whole, however, erosion has not occurred as extensively as would be expected from the topographic conditions, owing to the great tendency for the loessial material to stand in vertical cuts. Washing does not occur to a disastrous extent.

The terrace and bottomland soils are formed chiefly from the loessial material washed down from the uplands. In some cases there is a mixture of glacial drift but this is not sufficient to change the characteristics of the soils to any material extent.

## PHYSIOGRAPHY AND DRAINAGE

The original surface of the land, following the deposition of the loess, was probably more or less level. At least there were probably no striking topographic features and it had more the appearance of a broad plain. The surface has been greatly modified, by stream action and by erosion, and on the uplands the topography at present ranges from gently rolling to rough. The surface is characterized by rounded ridge tops and smooth gentle slopes leading down to the stream channels. The more hilly and rough areas are found in Jackson, Boyer, Cass, LaGrange, Raglan, Magnolia, Allen, Lincoln and eastern Jefferson townships. No areas are too rough for cultivation except the steep bluffs of the Knox silt loam which border the valley of the Missouri River. Here there has been some slipping and sliding of the loess on the bluffs and in general they are very steep and quite uncultivable, but to the east these slopes gradually merge into the rolling upland plain.

The first topographic division of the county consists of the typical gently rolling upland plains east of the river. The second division includes the rough slopes along the Missouri River that separate the bottomlands from the upland areas. The bluffs are frequently 200 to 300 feet high. The third topographic division of the county includes the deep broad alluvial valley of the Missouri River with the narrower, shallower, alluvial valleys of many of its tributary streams. These alluvial lands are largely first bottomlands, most of which are not subject to overflow. Terraces or second bottoms occur chiefly along Boyer, Soldier and Willow Rivers. They range from 5 to 50 feet above the stream channels. Along the Missouri River there are few distinct terraces, most of which are low and gradually merge into the bottoms. They vary from one-eighth to one-half mile in width and from one-fourth mile to a mile and a fourth in length.

The first bottomlands cover 44.5 percent of the total area. All of these bottomlands are above overflow except narrow strips along the smaller creeks and

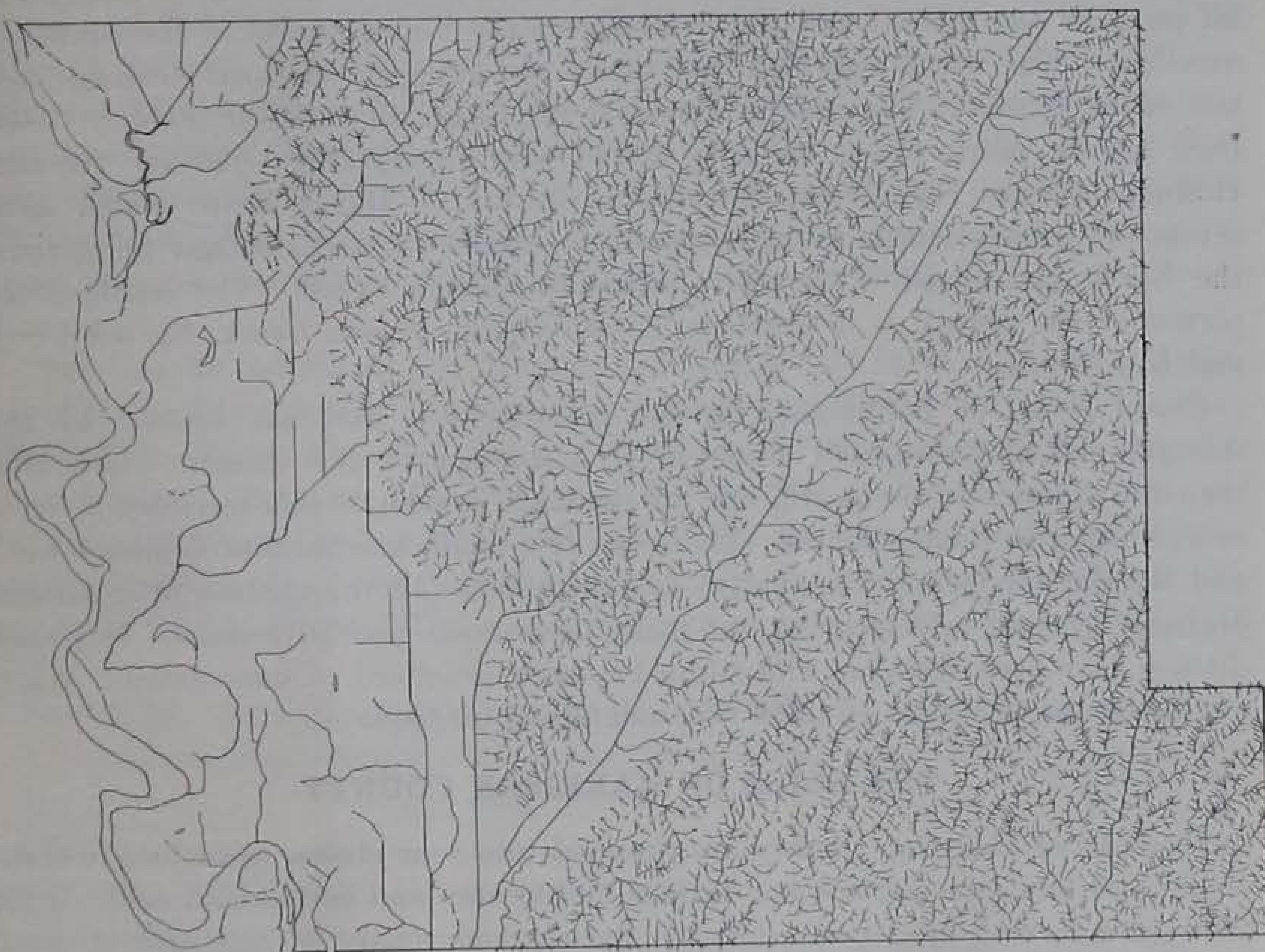


Fig. 2. Map showing natural drainage system of Harrison County.

drainageways. Since the channels of Boyer, Willow and Soldier Rivers and of Mosquito, Pigeon, Allen and Steer Creeks have been deepened and straightened, thousands of acres of first bottoms along these streams have been reclaimed from annual overflow. Along the streams which flow into the Missouri River, the bottomlands range from narrow strips 75 to 100 feet in width to broad bottoms from one to two miles wide. Along the Missouri River the bottoms range from 5½ to 10 miles in width. Along the channel of the river there is a narrow area of bottomland which consists chiefly of mud flats with some patches of sand, sand ridges, hummocks and dunes from 1 to 10 feet in height. These areas are subject to overflow quite regularly. This overflow area ranges from one-fourth of a mile to as much as two miles in width in some places. The border is constantly shifting, due to the action of the stream waters. Back of this flood plain, the second area of bottomland is 5 to 15 feet higher, and 20 to 30 feet above the normal water level. It is well above overflow. This plain is 5 to 9 miles wide and extends to the bluffs. The topography is generally flat and monotonous. There are, however, a few occasional ridges of sand parallel to old or present stream courses. Low narrow terraces usually separate this bottomland plain from the bluffs to the east.

The county is drained entirely by the Missouri River and its tributaries. The upland slopes gradually to the southwest. The streams flow in that general direction to the Missouri River lowlands, thru which they now pass in channels which have been straightened and deepened, but which originally were winding and tortuous. Branches of the various streams extend into practically all parts of the upland and the drainage of the upland areas of the county is excellent. The accompanying map shows the extensive natural drainage system of the county. The chief streams are the Little Sioux River, Soldier River, Deer Creek, Allen Creek, Willow River, with three large tributary streams, Hoffman Creek, Elk Creek, Thompson Creek, the Boyer River which flows across the county almost from northeast to southwest, and its chief tributaries, the North and South Picayune Creek and Harris Creek. The southeastern corner of the county is drained by Potato Creek, Pigeon Creek, Spring Creek and Key Creek.

Broad areas of bottomland in the southwestern part are crossed by the straightened and deepened channels of a number of the streams which flow thru the uplands to the north, but the drainage system of this territory is, however, limited to these streams. There are few or no intermittent drainage lines and the flat topography and heavy textured soils and the absence of a natural drainage system, to a large extent make these areas poorly drained. Drainage ditches have been installed and tiling has been practiced to some extent. Without tiling the drainage of these bottomlands is inadequate.

## THE SOILS OF HARRISON COUNTY

The soils of Harrison County are grouped into four classes according to their origin and location—drift, loess, terrace and swamp and bottomland soils. Drift soils were formed by deposits left by glaciers and consist of mixtures of sand, gravel and clay, and frequently contain pebbles and boulders. Loess soils are fine dust-like deposits laid down by the wind at some previous geological 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 occur in poorly drained areas or along streams, many of them being subject to more or less frequent overflow. The extent and occurrence of the four groups of soils in Harrison County are shown in table II.

Only a very limited area is covered by the drift soil, 0.3 per cent. This soil is found along the streams in narrow disconnected strips on the hill slopes. It occurs along the stream valleys of nearly all the rivers and creeks and their larger tributaries. By far the larger portion of the county is covered by the loess soils, 52.5 per cent. Loess occurs over practically all of the upland areas.

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

| Soil Group | Acres | Percent of total area of County |
|---|---|---|
| Drift soils | 1,280 | 0.3 |
| Loess soils | 232,064 | 52.5 |
| Terrace soils | 12,480 | 2.8 |
| Swamp and bottomland soils | 196,416 | 44.4 |
| Total | 442,240 | ---- |

Terrace soils are developed to a very limited extent, being found on only 2.8 percent of the total area. They occur in narrow strips and small areas along some of the more important streams along the bluffs adjacent to the broad bottomlands of the Missouri River. Swamp and bottomland soils are extensively developed. They cover 44.4 per cent of the total area. The entire area of Morgan, Clay and Cincinnati Townships and a large portion of St. John, Taylor, Raglan and Little Sioux Townships are covered by bottomland. Extensive areas are also developed along the various streams, chiefly along the Boyer River.

There are 21 individual soil types in the county and these with the colluvial phase of the Wabash silt loam, the deep phase of the Sarpy silt loam, the deep phase of the Sarpy silty clay loam and the area of Riverwash make a total of 25 soil areas. There are one drift soil, two loess types, three terrace soils and 19 areas of swamp and bottomland soils. The various soil types are distinguished on the basis of certain definite characteristics which are described in the appendix to this report. The names indicate certain group characteristics.

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN HARRISON COUNTY

| Soil No. | Soil Type | Acres | Percent of total area of county |
|---|---|---|---|
| | **DRIFT SOILS** | | |
| 1 | Carrington loam | 1,280 | 0.3 |
| | **LOESS SOILS** | | |
| 9 | Marshall silt loam | 202,432 | 45.8 |
| 11 | Knox silt loam | 29,632 | 6.7 |
| | **TERRACE SOILS** | | |
| 75 | Waukesha silt loam | 7,104 | 1.6 |
| 131 | Judson silt loam | 5,312 | 1.2 |
| 214 | Hancock fine sandy loam | 64 | 0.1 |
| | **SWAMP AND BOTTOMLAND SOILS** | | |
| 153 | Lamoure silt loam | 11,008 | 2.5 |
| 111 | Lamoure silty clay loam | 11,392 | 2.6 |
| 215 | Lamoure silty clay | 28,544 | 6.5 |
| 26 | Wabash silt loam | 41,280 | 15.0 |
| 26a | Wabash silt loam (colluvial phase) | 27,328 | |
| 48 | Wabash silty clay loam | 9,408 | 2.1 |
| 27 | Wabash silty clay | 14,272 | 3.2 |
| 106 | Cass silt loam | 10,752 | 2.4 |
| 51 | Cass silty clay loam | 11,584 | 2.6 |
| 216 | Cass silty clay | 8,000 | 1.8 |
| 217 | Cass very fine sandy loam | 1,600 | 0.4 |
| 89 | Sarpy silt loam | 5,120 | 1.6 |
| 218 | Sarpy silt loam (deep phase) | 1,920 | |
| 219 | Sarpy silty clay loam (deep phase) | 384 | 0.1 |
| 220 | Sarpy silty clay | 4,992 | 1.1 |
| 28 | Sarpy very fine sandy loam | 2,816 | 0.6 |
| 133 | Sarpy fine sand | 832 | 0.2 |
| 195 | Ray silt loam | 512 | 0.1 |
| 53 | Riverwash | 4,672 | 1.0 |
| | Total | 442,240 | ---- |

The areas covered by the various soil types are shown in table III. The Carrington loam, the only drift soil, covers only 0.3 percent of the total area. The Marshall silt loam is the largest loess type and is by far the most extensively developed soil type. It covers 45.8 percent of the total area and is found in large individual areas over all the upland sections. The Knox silt loam is the second largest loess soil and the third largest soil type. It covers 6.7 percent of the total area. The three terrace types are all rather limited in area, the Waukesha silt loam, the most extensive, covers 1.6 percent of the county; the Judson silt loam is smaller, covering 1.2 percent; while the Hancock fine sandy loam is very limited in area. On the bottomlands the Wabash silt loam with the colluvial phase, is the most extensively developed type, covering 15 percent of the total area. It is the second largest soil type. The Lamoure silty clay is second in area on the bottoms, covering 6.5 percent of the county. It is the fourth largest individual soil. The Wabash silty clay covers 3.2 percent of the county. The Cass silty clay loam, and the Lamoure silty clay loam each cover 2.6 percent, while the Lamoure silt loam is found on 2.5 percent of the area. The Cass silt loam covers 2.4 percent, the Wabash silty clay loam 2.1 percent, the Cass silty clay 1.8 percent, the Sarpy silt loam 1.6 percent, the Sarpy silty clay 1.1 percent and the remaining bottomland soils 1 percent or less of the total area.

## The Fertility in Harrison County Soils

Samples were taken for analysis from each soil type except the Sarpy silty clay and the area of Riverwash which were not sampled because of their small area and because of the great variation in the character of the Riverwash.

The more extensive soil types were sampled in triplicate, while only one sample was taken from each of the minor types. All samplings were made with the greatest care so that the samples should be representative of the individual soil types and that all variations due to previous treatments of the soil might be eliminated. The samples were taken at three depths, 0 to 6 2/3 inches, 6 2/3 to 20 inches and 20 to 40 inches, representing the surface 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 phosphorus, nitrogen and carbon determinations, and the Truog qualitative test was used in the determination of the limestone requirement. The figures given in the tables are the averages of the results of duplicate determinations of all samples of each type and they represent, therefore, the averages of two or six determinations.

### THE SURFACE SOILS

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

Wide variations occur in the phosphorus content of the various soil types, ranging from 1,091 pounds in the Sarpy fine sand up to 2,690 pounds in the Wabash silty clay loam, both bottomland soils. No definite relationship is evident between the phosphorus content of the various soils and the different soil groups. The bottomland types on the average are a little better supplied than

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

Pounds per acre of 2 million pounds of surface soil (0-6⅔")

| Soil No. | Soil Type | Total phosphorus | Total nitrogen | Total organic carbon | Total inorganic carbon | Limestone requirement |
|---|---|---|---|---|---|---|
| | DRIFT SOILS | | | | | |
| 1 | Carrington loam | 1,171 | 3,000 | 37,243 | ------ | 1,000 |
| | LOESS SOILS | | | | | |
| 9 | Marshall silt loam | 1,329 | 2,840 | 32,596 | ------ | 1,000 |
| 11 | Knox silt loam | 1,075 | 1,900 | 21,224 | 25,676 | ------ |
| | TERRACE SOILS | | | | | |
| 75 | Waukesha silt loam | 1,817 | 3,340 | 39,680 | ------ | ------ |
| 131 | Judson silt loam | 1,791 | 4,200 | 44,560 | ------ | 1,000 |
| 214 | Hancock fine sandy loam | 1,198 | 1,840 | 13,742 | 10,836 | ------ |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 153 | Lamoure silt loam | 2,216 | 3,100 | 42,451 | 2,574 | ------ |
| 111 | Lamoure silty clay loam | 1,711 | 3,600 | 36,536 | 686 | ------ |
| 215 | Lamoure silty clay | 1,912 | 3,040 | 50,501 | 588 | ------ |
| 26 | Wabash silt loam | 1,387 | 3,160 | 38,725 | ------ | ------ |
| 26a | Wabash silt loam (colluvial phase) | 1,454 | 2,360 | 29,435 | ------ | ------ |
| 48 | Wabash silty clay loam | 2,690 | 4,840 | 53,939 | ------ | ------ |
| 27 | Wabash silty clay | 1,845 | 5,000 | 54,843 | ------ | 2,000 |
| 106 | Cass silt loam | 1,575 | 2,720 | 32,993 | 163 | ------ |
| 51 | Cass silty clay loam | 1,549 | 3,080 | 47,824 | 333 | ------ |
| 216 | Cass silty clay | 1,535 | 4,080 | 47,188 | ------ | ------ |
| 217 | Cass very fine sandy loam | 1,549 | 1,680 | 18,989 | 8,428 | ------ |
| 89 | Sarpy silt loam | 1,596 | 2,500 | 31,119 | 11,037 | ------ |
| 218 | Sarpy silt loam (deep phase) | 1,764 | 1,680 | 18,813 | 15,150 | ------ |
| 219 | Sarpy silty clay loam (deep phase) | 1,684 | 2,080 | 20,257 | 8,629 | ------ |
| 28 | Sarpy very fine sandy loam | 1,293 | 1,280 | 14,546 | 11,620 | ------ |
| 133 | Sarpy fine sand | 1,091 | 520 | 5,265 | 7,159 | ------ |
| 195 | Ray silt loam | 1,818 | 2,240 | 27,897 | 3,354 | ------ |

the upland soils, which might be expected from the fact that there has been less plant growth on these types and hence a smaller removal of the element phosphorus. Comparing the various individual series and soil types, however, the relationships are somewhat more clearly shown.

On the loessial uplands the Marshall silt loam is richer in phosphorus than the Knox silt loam; on the terraces the Waukesha silt loam and the Judson silt loam are much better supplied than the Hancock fine sandy loam. There is very little difference between the two former types. The low content of the Hancock soils is undoubtedly largely due to the difference in texture. On the bottomlands the Lamoure and Wabash soils are better supplied with phosphorus than are the Cass and Sarpy types. This would be expected from the characteristics of the soil series concerned. The Cass types on the average are somewhat better supplied than the Sarpy soils, which also would be expected.

Probably some relationship exists between the phosphorus content of the soil and the characteristics which are used as the basis for distinguishing the various soil series. Thus there are differences in topography, in the color of the soil and in the subsoil characteristics. Those types in general which are darker in color, more level in topography, and have heavier subsoils, contain a larger quantity of phosphorus. These relationships are apparent when the Marshall and Knox types are compared on the loessial uplands and when the Wabash and Lamoure soils which are darker in color and have heavier subsoils are compared with the Cass and Sarpy soils on the bottomlands.

Ordinarily the relationship between the phosphorus content of the soils and the texture is more definitely shown than the relationship to soil groups or soil series. It is not possible to make any comparisons among the upland soils as only one type of each series has been mapped. The same is true of the terrace soils. On the bottomlands, the Lamoure silt loam is a little higher than the silty clay loam or the silty clay, but this is probably due to a peculiarity of the particular samples analyzed as ordinarily the silty clay loam and silty clay would be somewhat higher than the silt loam. Among the Wabash soils the silty clay loam is the highest, while the silty clay is second and the silt loam and the colluvial phase of the silt loam are lower in phosphorus. There is very little difference among the types in the Cass series. The very fine sandy loam is higher than would ordinarily be the case and the silty clay loam, silty clay and the silt loam are very similar in content, but in most cases these types would be better supplied with phosphorus than the coarse textured types. Among the Sarpy soils, the deep phase of the Sarpy silt loam and the deep phase of the silty clay loam, are much higher than the other Sarpy soils. The silt loam is just slightly lower than the types mentioned while the very fine sandy loam and fine sand are very low in this constituent.

Considering the analyses as a whole, it is evident that previous observations concerning the relationship between texture and phosphorus content are very largely confirmed. In general, fine textured types are better supplied than coarse textured soils; silty clay loams are usually richer than silt loams, loams and sandy loams; silt loams ordinarily contain a higher content of phosphorus than the sandy types; and loams are usually higher than the sandy or fine sandy types of the same series.

It is apparent that the phosphorus supply in the soils is not adequate to meet the needs of crops on these soils for an indefinite period. Phosphorus fertilizers will be needed very soon. Probably, as indicated by greenhouse and field experiments on the same soil types in other counties, phosphate fertilizers might prove profitable at the present time. Tests of both rock phosphate and superphosphate (acid phosphate) are very desirable.

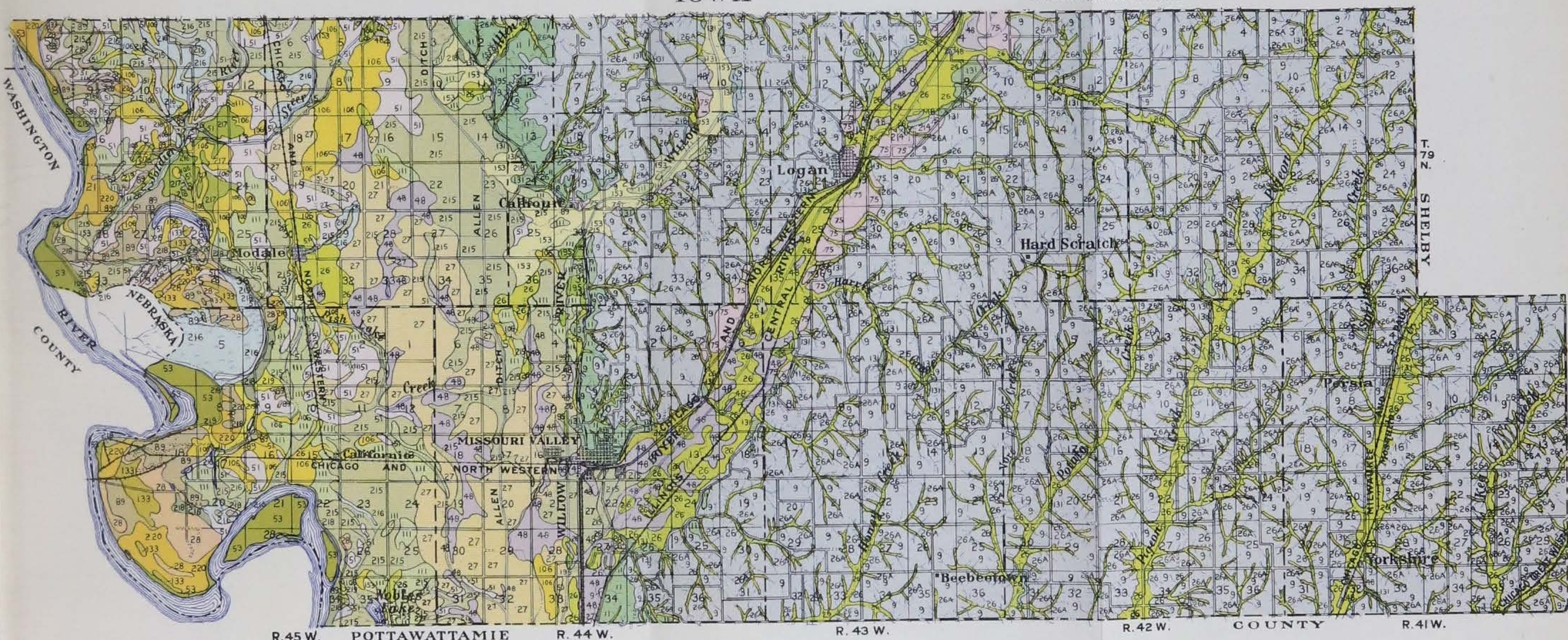
In nitrogen content the soils varied even more widely than in phosphorus. The amount present ranged from 520 pounds per acre in the Sarpy fine sand up to 5,000 pounds per acre in the Wabash silty clay. No relationship between the nitrogen content of the soil and the various soil groups is evident. The bottomland types are somewhat better supplied on the average than the upland soils, but there are very wide variations on the bottoms due to the wide differences in the characteristics of individual soil types. The series characteristics, however, seem to have some effect upon the nitrogen content. Thus, on the loessial uplands

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

# SOUTH SECTION
# SOIL MAP OF HARRISON COUNTY IOWA

U. S. DEPT. OF AGRICULTURE, BUREAU OF CHEMISTRY AND SOILS
Henry G. Knight, Chief. A. G. McCALL, Chief, Soil Investigations
Curtis F. Marbut, in charge Soil Survey

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




## LEGEND

*Loess Soils*

- 9 — Marshall silt loam
- 11 — Knox silt loam

*Drift Soil*

- 1 — Carrington loam

*Terrace Soils*

- 75 — Waukesha silt loam
- 131 — Judson silt loam
- 214 — Hancock fine sandy loam

*Swamp and Bottomland Soils*

- 153 — Lamoure silt loam
- 215 — Lamoure silty clay
- 111 — Lamoure silty clay loam
- 26 — Wabash silt loam
- 26A — Wabash silt loam (Colluvial phase)
- 48 — Wabash silty clay loam
- 27 — Wabash silty clay
- 106 — Cass silt loam
- 51 — Cass silty clay loam
- 216 — Cass silty clay
- 217 — Cass very fine sandy loam
- 89 — Sarpy silt loam
- 218 — Sarpy silt loam (Deep phase)
- 219 — Sarpy silty clay loam (Deep phase)
- 220 — Sarpy silty clay
- 28 — Sarpy very fine sandy loam
- 133 — Sarpy fine sand
- 195 — Ray silt loam
- 53 — Riverwash

**SCALE: 1 INCH TO 2½ MILES**

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

the Marshall is richer in nitrogen than the Knox. On the terraces the Waukesha and Judson are better supplied than the Hancock and on the bottoms the Lamoure and Wabash types are generally better supplied than the Cass and Sarpy soils, altho the heavier textured Cass soils are almost as high as the Wabash and Lamoure types.

The effects of textural differences among the soils are shown when the various types on the bottoms are compared within series. Thus the Lamoure silty clay loam is the richest of the Lamoure types, the Wabash silty clay loam and the Wabash silty clay are the richest among the Wabash soils. The Cass silty clay loam and Cass silty clay are the richest of the Cass types, and the Sarpy silty clay loam, deep phase, is the richest of the Sarpy soils. The Sarpy very fine sandy loam is lower than the silt loam and the fine sand of the same series is the lowest in nitrogen of any of the soils. Such comparisons are not possible among the upland soils, owing to only one soil type from each series being mapped. Apparently, the characteristics which serve to distinguish the soil series and the textural differences among the soil types are very largely responsible for differences in the nitrogen content. Types developed on the more level to flat areas, very black in color, more poorly drained and with heavier subsoils are higher in nitrogen, and the fine-textured types contain much more of this element. Silty clay loams are richer than silt loams. Loams are better supplied with nitrogen than sandy loams. Sandy loams are higher in the element than sands.

The supply of nitrogen in the soils is not strikingly deficient except in the Sarpy fine sand, but nitrogen must be considered when systems of permanent fertility are being planned. Some fertilizing materials supplying nitrogen must be employed on these soils at regular intervals to maintain the fertility of the land. Farm manure is the most important and valuable fertilizing material supplying nitrogen and it plays a large part in building up and keeping up the nitrogen supply of the soil. The proper utilization of all crop residues will also aid materially in maintaining the nitrogen supply. On grain farms the use of well inoculated legumes as green manures must be resorted to, to supply nitrogen. On many livestock farms the practice of green manuring may be a very desirable supplement to farm manure, as an aid in keeping up the nitrogen content. Green manuring is a very desirable practice for use on many of the soils in Harrison County.

The nitrogen content of the soil usually bears a definite relation to the amount of organic carbon present. Usually the soils which are lacking in nitrogen are low in organic matter. Likewise soils which are known to be deficient in organic matter, which is apparent by their light color, are generally assumed to be lacking in nitrogen. In fact the color of a soil usually indicates fairly accurately the content of organic matter and nitrogen. If a soil is very light, organic material and nitrogen are lacking, while if the color is dark, it may generally be assumed that the supply is adequate, at least for the present.

The organic carbon content of the soils varies widely as is apparent from the analyses. The amount present ranges from 5,265 pounds per acre in the Sarpy fine sand up to 54,843 pounds per acre in the Wabash silty clay. These are the same types which were the lowest and highest, respectively, in nitrogen content.

As with nitrogen, there is little evidence of any relationship between the organic matter content of the soils and the various soil groups, altho the bottomland soils are on the average much better supplied than the upland and terrace soils. The relationships among the various soil series are similar to those noted in the case of nitrogen and the relationships among the soil types are also similar to those already discussed.

On the uplands, the Marshall silt loam is higher in organic matter than the Knox silt loam. On the terraces the Waukesha and Judson soils are richer than the Hancock types. On the bottomlands the Lamoure and Wabash soils are better supplied with organic matter on the average than are the Cass and Sarpy soils. However, the heavier types of the Cass series are about as rich in organic matter as the Lamoure and Wabash soils. Some effects of textural differences may also be noted. The Lamoure silty clay on the bottomland is richer than the silty clay loam or the silt loam. The silt loam is a little higher than the silty clay loam, which is contrary to the usual results, probably due to some abnormality in the particular sample. The Wabash silty clay is a little higher than the Wabash silty clay loam, and both are much better supplied with organic matter than the Wabash silt loam or the colluvial phase of this latter type. The Cass silty clay loam and the Cass silty clay are the richest among the Cass series, while the very fine sandy loam is very much lower in organic matter. The Sarpy silt loam, is the richest of the Sarpy types, being somewhat higher than the deep phase of the silty clay loam. This is undoubtedly due to some abnormal condition pertaining to the particular sample. The very fine sandy loam and the fine sand are very low in organic matter, the fine sand being the lowest in this constituent of all the soil types. It is apparent that the series characteristics of the various soils and textural differences have a very large effect on the organic matter content of individual soil types.

The relationship between the content of nitrogen and the amount of organic carbon in soils indicates the rapidity with which the plant food in the soils is being changed into an available form. In many of the soils in this county, this relationship is such that it is evident that the decomposition processes are not proceeding as rapidly as they should and there is certainly an inadequate production of available plant food constituents. On such soils farm manure is especially valuable, due to the fact that it supplies the microorganisms which bring about the decomposition of the unavailable constituents in the soil and increase the production of available plant food.

Farm manure is of especially large value on the types low in organic matter and lighter in color. On such soils its value is due mainly to the supplying of organic matter. Even on the bottomland types, however, small amounts of farm manure will often be of large value in stimulating the production of available plant food. Large amounts should not be applied to these types, but on the upland soils rather large amounts of farm manure are very desirable. On the Marshall silt loam, on the Carrington loam and especially on the Knox silt loam the need of organic matter supplied in the form of farm manure is very evident, and large increases in crop yields follow its application. On the terraces the various soil types will also respond to additions of farm manure, and on the coarse-textured soils on the bottomlands large amounts of farm manure will prove of value. On the heavier bottomland types which are black in color small amounts of farm manure may frequently be applied with profit, but manure should never be added preceding a small grain crop, as it has a tendency to cause the crop to lodge.

Where farm manure is not available the use of a leguminous crop as a green manure is very desirable.

The Knox silt loam is the only upland soil showing any content of inorganic carbon. It is the only one of the types, therefore, which is not acid in reaction. The Marshall silt loam and the Carrington loam, the two remaining upland soils, are slightly acid in reaction and show a small need for lime. Neither of these soils is high in acidity, and the need for lime is not great. On the terraces the Hancock fine sandy loam is high in inorganic carbon and not in need of lime. The Judson silt loam is slightly acid, while the Waukesha silt loam altho having no content of inorganic carbon shows no lime requirement. On the bottomlands the Wabash silty clay is the only type which shows a lime requirement. None of the other soils shows any acidity and all but the Wabash types have a content of inorganic carbon which in some cases is very large.

Acid soils may not give the best yields of general farm crops, and legume crops will not make the most satisfactory growth on such soils. It is very desirable, therefore, that on the Carrington loam, the Marshall silt loam, the Judson silt loam, the Waukesha silt loam, the Wabash silty clay and the other Wabash types, the soils be tested for lime needs and that lime be applied in the amounts that the test shows to be necessary, if the best yields of such crops as sweet clover and alfalfa are to be secured. The amount needed on these types is indicated in the table, but the figures given are merely indicative of the requirements of the soil. Lime should never be applied to land until the soil has been tested and the amount required has been determined. On the soils mentioned, tests are recommended if legumes are to be grown. For general farm crops the need for lime is not so evident, but even in such cases the use of lime may prove of value.

## THE SUBSURFACE SOILS AND SUBSOILS

Tables V and VI give the results of the analyses of the subsurface soils and subsoils. These are calculated on the basis of 4 million pounds of subsurface soil and 6 million pounds of subsoil per acre.

The fertility of the soil is affected very little by the plant food content of the lower soil layers, unless there is a large amount of some constituent present or a striking deficiency. In general the analyses of the surface soils in this county show fairly accurately the plant food content and the crop producing power of the soils. They also indicate the need for fertilizer additions. The lower soil layers are not particularly high in any constituents nor are they strikingly deficient. It is not necessary, therefore, to discuss these analyses in detail.

The results as a whole confirm the conclusions which have been reached in the discussion of the analyses of the surface soils. Phosphorus fertilizers will certainly be needed on these soils in the near future as there is no large supply of this constituent. The use of phosphorus fertilizers might prove profitable on these types at the present time. On some soils organic matter and nitrogen

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

Pounds per acre of 4 million pounds of subsurface soil (6⅔ to 20")

| Soil No. | Soil Type | Total phosphorus | Total nitrogen | Total organic carbon | Total inorganic carbon | Limestone requirement |
|---|---|---|---|---|---|---|
| | DRIFT SOILS | | | | | |
| 1 | Carrington loam | 1,912 | 2,000 | 21,071 | ------ | ------ |
| | LOESS SOILS | | | | | |
| 9 | Marshall silt loam | 2,576 | 3,387 | 41,965 | ------ | 1,000 |
| 11 | Knox silt loam | 2,896 | 2,240 | 20,211 | 60,858 | ------ |
| | TERRACE SOILS | | | | | |
| 75 | Waukesha silt loam | 3,470 | 5,120 | 53,302 | ------ | ------ |
| 131 | Judson silt loam | 3,204 | 6,640 | 80,797 | ------ | 1,000 |
| 214 | Hancock fine sandy loam | 2,747 | 3,120 | 34,171 | 30,399 | ------ |
| | SWAMP AND BOTTOMLAND SOILS | | | | | |
| 153 | Lamoure silt loam | 4,053 | 6,400 | 85,354 | 5,004 | ------ |
| 111 | Lamoure silty clay loam | 2,586 | 5,040 | 47,185 | 232 | ------ |
| 215 | Lamoure silty clay | 3,368 | 3,200 | 65,232 | 4,903 | ------ |
| 26 | Wabash silt loam | 2,882 | 5,840 | 62,329 | ------ | ------ |
| 26a | Wabash silt loam (colluvial phase) | 1,992 | 3,040 | 63,160 | ------ | ------ |
| 48 | Wabash silty clay loam | 4,226 | 6,400 | 76,643 | ------ | ------ |
| 27 | Wabash silty clay | 2,774 | 4,080 | 91,636 | ------ | 1,000 |
| 106 | Cass silt loam | 2,800 | 2,160 | 40,921 | 1,914 | ------ |
| 51 | Cass silty clay loam | 2,774 | 2,720 | 35,844 | 2,550 | ------ |
| 216 | Cass silty clay | 2,882 | 5,120 | 51,000 | 1,332 | ------ |
| 217 | Cass very fine sandy loam | 2,962 | 2,800 | 29,835 | 21,409 | ------ |
| 89 | Sarpy silt loam | 2,896 | 1,880 | 18,314 | 31,826 | ------ |
| 218 | Sarpy silt loam (deep phase | 2,720 | 1,440 | 30,841 | 13,628 | ------ |
| 219 | Sarpy silty clay loam (deep phase) | 2,800 | 2,160 | 33,531 | 11,374 | ------ |
| 28 | Sarpy very fine sandy loam | 2,828 | 1,920 | 23,683 | 25,692 | ------ |
| 133 | Sarpy fine sand | 1,979 | 320 | 5,834 | 13,958 | ------ |
| 195 | Ray silt loam | 4,256 | 6,320 | 122,055 | 1,645 | ------ |

should be added now, and on all the soils the use of fertilizing materials supplying these constituents is very necessary if the supply is to be maintained and the soils are to continue productive. The addition of organic matter and nitrogen may be accomplished thru the proper use of farm manure, crop residues and the turning under of leguminous crops as green manures. The same soils which were acid in the surface soils are acid thru the subsoil with the exception of the Carrington loam which shows a lime content in the lower soil layers. With the exception of this type, therefore, the soils which show a need for lime, according to the analyses of the surface soil, should be tested, and lime should be applied if the best growth of general farm crops and particularly of legumes is to be secured. The testing of the Marshall silt loam, the Waukesha silt loam, the Judson silt loam and the Wabash soils on the bottoms is very necessary, and the use of lime is very desirable on these types.

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

Pounds per acre of 6 million pounds of subsoil (20 to 40")

| Soil No. | Soil Type | Total phosphorus | Total nitrogen | Total organic carbon | Total inorganic carbon | Limestone requirement |
|---|---|---|---|---|---|---|
| | **DRIFT SOILS** | | | | | |
| 1 | Carrington loam | 3,717 | 1,680 | 18,086 | 30,447 | ------ |
| | **LOESS SOILS** | | | | | |
| 9 | Marshall silt loam | 3,325 | 2,880 | 52,630 | ------ | 1,000 |
| 11 | Knox silt loam | 4,262 | 1,380 | 15,313 | 98,783 | ------ |
| | **TERRACE SOILS** | | | | | |
| 75 | Waukesha silt loam | 4,888 | 4,740 | 39,108 | ------ | ------ |
| 131 | Judson silt loam | 4,887 | 8,640 | 100,280 | ------ | 1,000 |
| 214 | Hancock fine sandy loam | 3,111 | 2,040 | 22,132 | 58,836 | ------ |
| | **SWAMP AND BOTTOMLAND SOILS** | | | | | |
| 153 | Lamoure silt loam | 5,171 | 8,160 | 105,386 | 14,189 | ------ |
| 111 | Lamoure silty clay loam | 4,323 | 4,920 | 40,366 | 15,756 | ------ |
| 215 | Lamoure silty clay | 4,848 | 3,960 | 66,576 | 44,991 | ------ |
| 26 | Wabash silt loam | 4,767 | 8,520 | 92,122 | ------ | ------ |
| 26a | Wabash silt loam (colluvial phase) | 3,960 | 3,240 | 79,482 | ------ | 2,000 |
| 48 | Wabash silty clay loam | 5,010 | 8,400 | 131,122 | ------ | ------ |
| 27 | Wabash silty clay | 3,474 | 8,880 | 88,780 | ------ | 1,000 |
| 106 | Cass silt loam | 3,837 | 840 | 26,184 | 15,003 | ------ |
| 51 | Cass silty clay loam | 4,119 | 3,360 | 19,565 | 49,275 | ------ |
| 216 | Cass silty clay | 3,231 | 1,080 | 15,094 | 20,710 | ------ |
| 217 | Cass very fine sandy loam | 4,605 | 4,560 | 39,651 | 29,515 | ------ |
| 89 | Sarpy silt loam | 3,858 | 1,260 | 11,633 | 47,657 | ------ |
| 218 | Sarpy silt loam (deep phase) | 4,971 | 3,960 | 70,642 | 19,770 | ------ |
| 219 | Sarpy silty clay loam (deep phase) | 4,524 | 2,400 | 52,700 | 22,504 | ------ |
| 28 | Sarpy very fine sandy loam | 3,111 | 1,680 | 18,065 | 34,419 | ------ |
| 133 | Sarpy fine sand | 3,109 | 420 | 3,294 | 29,327 | ------ |
| 195 | Ray silt loam | 5,856 | 5,760 | 156,987 | 1,992 | ------ |

## GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on the Marshall silt loam and the Knox silt loam from Harrison County in order to secure some information regarding the fertilizer needs of these soils and regarding the value of the application of certain fertilizing materials. Experiments are also included on the Knox silt loam from Plymouth County and on the Marshall silt loam from Fremont County, from Crawford County and from Woodbury County. Inasmuch as these are the same soil types found in Harrison County, the results are certainly directly applicable to conditions there.

The fertilizer treatments employed included superphosphate, rock phosphate, a complete commercial fertilizer, limestone, manure and muriate of potash. These materials were applied in the amounts in which they are usually employed in the field and the results are, therefore, indicative of what may be expected on the farms. Manure was added at the rate of 10 tons per acre, lime was applied

Fig. 3. Clover on Marshall silt loam, greenhouse experiment.

in an amount sufficient to neutralize the acidity of the soil. The superphosphate was applied at the rate of 250 pounds per acre, the rock phosphate at the rate of one ton per acre, the muriate of potash at the rate of 50 pounds per acre, and the complete commercial fertilizer at the rate of 300 pounds per acre.

Wheat and clover were grown, the clover being seeded about one month after the wheat was up. In the experiment on the Marshall silt loam from Harrison County only the clover yield was obtained.

THE RESULTS ON THE MARSHALL SILT LOAM

The results of the experiment on the Marshall silt loam from Harrison County are given in table VII. The figures are the averages of the weight of the clover in grams on the duplicate pots. Superphosphate brought about a very large increase in the yield of clover. Limestone with superphosphate gave a further considerable increase in the yields. Manure alone increased the yield over the check and gave a somewhat larger increase than the superphosphate alone. The superphosphate applied with the manure brought about a very large increase over that occasioned by the manure alone. Limestone applied with the manure and superphosphate showed a further increase in yield. The muriate of potash applied with the manure, limestone and superphosphate showed a very slight increase in the clover.

Apparently this soil will respond profitably to applications of manure, lime and superphosphate. Manure may be considered a basic treatment and will have large value on all the general farm crops grown in the rotation. The use of lime is very desirable when legumes are to be grown and it will show its largest effects on these crops. The use of superphosphate in addition to manure and

TABLE VII. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, HARRISON COUNTY

| Pot No. | Treatment | Weight of clover in grams |
|---|---|---|
| 1 | Check | 7.4 |
| 2 | Superphosphate | 20.3 |
| 3 | Limestone+superphosphate | 28.0 |
| 4 | Manure | 25.9 |
| 5 | Manure+superphosphate | 39.2 |
| 6 | Manure+limestone+superphosphate | 44.9 |
| 7 | Manure+limestone+superphosphate+potassium | 45.9 |

TABLE VIII. GREENHOUSE EXPERIMENT, KNOX SILT LOAM, HARRISON COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 3.8 | 3.5 |
| 2 | Superphosphate | 5.2 | 22.6 |
| 3 | Manure | 5.2 | 31.6 |
| 4 | Manure+superphosphate | 5.7 | 34.2 |
| 5 | Manure+superphosphate+potassium | —— | 31.0 |

limestone is apparently very desirable on this soil. Tests of this phosphate fertilizer on individual farms are strongly recommended.

THE RESULTS ON THE KNOX SILT LOAM

The results secured in the greenhouse experiment on the Knox silt loam from Harrison County are given in table VIII. Superphosphate increased the yield of wheat and brought about an enormous increase in the yield of clover. The manure alone increased the yield of wheat considerably over the check and gave about the same results as the superphosphate, but on the clover, however, it brought about a larger increase than did the superphosphate. When the superphosphate was applied with the manure a gain was noted in the yield of wheat and also in the yield of clover. Muriate of potash with the manure and superphosphate showed no increase in the clover. The yield of wheat was not secured.

On this soil type the effects of manure and superphosphate are very clearly shown. The type is low in organic matter and additions of farm manure or leguminous green manures are very desirable. The use of superphosphate may be very desirable on the soil and may bring about very profitable increases in the yields of general farm crops. Tests on individual farms are strongly recommended.

THE RESULTS ON THE KNOX SILT LOAM FROM PLYMOUTH COUNTY

The results secured on the greenhouse experiment on the Knox silt loam from Plymouth County are given in table IX. Superphosphate increased the yield of wheat and brought about an enormous increase in the yield of the clover. Manure alone gave about the same effect as the superphosphate in the case of the wheat but showed less effect on the clover. Superphosphate with manure brought

Fig. 4. Clover on Knox silt loam, greenhouse experiment.

TABLE IX. GREENHOUSE EXPERIMENT, KNOX SILT LOAM, PLYMOUTH COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 5.8 | 7.7 |
| 2 | Superphosphate | 7.1 | 33 7 |
| 3 | Manure | 7.8 | 29.1 |
| 4 | Manure+superphosphate | 9.2 | 51.1 |
| 5 | Manure+superphosphate+potassium | 10.4 | 42.8 |

about a large increase in the yield of the wheat and greatly increased the yield of the clover. When the muriate of potash was added with the manure and superphosphate, the largest increase in the yield of wheat was secured, but the effect was not evidenced on the yield of clover.

It is apparent again, from this test, that the Knox silt loam will respond very profitably to applications of manure and a phosphate fertilizer. The use of manure is especially desirably, and the addition of superphosphate is strongly recommended. Potassium fertilizers may be desirable in individual cases, but tests are recommended before any extensive addition is made.

THE RESULTS ON THE MARSHALL SILT LOAM FROM FREMONT COUNTY

The results secured in the greenhouse experiment on the Marshall silt loam from Fremont County are given in table X. The superphosphate brought about an increase in the yield of wheat on this soil and a very large increase in the yield of clover. Limestone with the superphosphate had no effect on the wheat and a very slight influence on the clover. The manure alone showed about the same effect on the wheat as that shown by the superphosphate, but it had a much smaller effect on the clover. When the superphosphate was applied with the manure, it showed no effect on the wheat but brought about a very large increase in the yield of clover. The limestone applied with the manure and superphosphate showed a gain in the wheat crop and a slight influence on the clover. The muriate of potash applied with the manure, limestone and superphosphate had no effect on the wheat or the clover.

These results largely confirm those secured on the same soil type in Harrison County, indicating that this soil type will respond profitably to applications of manure, lime and superphosphate. Lime is particularly desirable in connection with the growing of a legume crop, and the addition of superphosphate is strongly recommended. There is no evidence of value from the use of the potash fertilizer.

TABLE X. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, FREMONT COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 12.2 | 10.4 |
| 2 | Superphosphate | 14.5 | 43.2 |
| 3 | Limestone+superphosphate | 13.8 | 43.5 |
| 4 | Manure | 14.6 | 30.4 |
| 5 | Manure+superphosphate | 14.2 | 51.9 |
| 6 | Manure+limestone+superphosphate | 15.4 | 52.5 |
| 7 | Manure+limestone+superphosphate+potassium | 15.4 | 49.7 |

TABLE XI. GREENHOUSE EXPERIMENT, MARSHALL SILT LOAM, CRAWFORD COUNTY

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of clover in grams |
|---|---|---|---|
| 1 | Check | 8.66 | 16.16 |
| 2 | Manure | 12.56 | 30.66 |
| 3 | Manure+limestone | 13.20 | 38.00 |
| 4 | Superphosphate | 11.70 | 43.33 |
| 5 | Manure+superphosphate | 11.96 | 56.83 |
| 6 | Limestone+superphosphate | 12.23 | 43.50 |
| 7 | Manure+limestone+superphosphate | 14.26 | 51.66 |
| 8 | Manure+limestone+superphosphate+potassium | 13.25 | 64.16 |

THE RESULTS ON THE MARSHALL SILT LOAM FROM CRAWFORD COUNTY

The results secured in the greenhouse experiment on the Marshall silt loam from Crawford County are given in table XI. Manure brought about a large increase in the yield of wheat and a very large increase in the yield of clover. Limestone with the manure showed a slight effect on the wheat crop and a very pronounced effect on the clover. Superphosphate alone had less effect on the wheat than did the manure alone but it showed a much larger effect on the clover. Manure and superphosphate showed a larger effect than the phosphate alone on the wheat and brought about a very much larger effect on the clover. Limestone and superphosphate showed a greater effect on the wheat than the superphosphate alone and about the same influence on the clover. Manure, lime and superphosphate gave the largest increase in the yields of wheat and only a slightly smaller effect on the clover than that brought about by the manure and phosphate without lime. When the muriate of potash was added with the manure, limestone and superphosphate, a smaller effect was brought about on the wheat than without the muriate, but on the clover there was a large increase in the yield.

These results are largely confirmatory of those previously secured. The value of manure is definitely evidenced. Limestone is certainly valuable in connection with the growing of a legume crop, and the addition of superphosphate is very desirable for general farm crops, especially when applied in addition to the basic treatments of manure and limestone. Potash fertilizers cannot be recommended until tests have been carried out and beneficial effects of the treatment definitely shown.

THE RESULTS ON THE MARSHALL SILT LOAM FROM WOODBURY COUNTY

The results of the experiment on the Marshall silt loam from Woodbury County are given in table XII. The figures are the averages of the weights of the wheat grain and clover in grams on the duplicate pots. Manure increased the yield of wheat and had a small effect on the clover. Lime, in addition to manure, increased the wheat crop considerably but showed no effect on the clover. This is contrary to the usual results. Ordinarily lime will show up particularly well on the legume crop of the rotation and in many cases its beneficial effects are not apparent on the corn and small grains. In this case, the effect was very large on the wheat and not so definite on the clover. The rock phosphate had a

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

| Pot No. | Treatment | Weight of wheat grain in grams | Weight of 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+superphosphate | 9.247 | 48.5 |
| 6 | Manure+lime+complete commercial fertilizer | 10.216 | 45.0 |

very slight effect on the yields of wheat and little or no effect on the clover. Superphosphate, however, brought about a very distinct effect on the wheat and a large increase in the yield of clover. The complete commercial fertilizer exerted a greater effect than the superphosphate on the wheat crop but had a slightly less effect on the clover.

Apparently this soil will respond profitably to manure, lime and a phosphate. Manure seems to be of considerable value and lime along with it may benefit not only the legume but also the grain crops of the rotation. Superphosphate seems to have a greater effect than rock phosphate in this particular case and in general it would seem that the use of superphosphate might be more desirable than rock phosphate. The complete commercial fertilizer was more effective than the superphosphate on the wheat but had less effect on the clover. Probably, however, superphosphate will generally prove more profitable than the complete fertilizer because of its lower cost.

## FIELD EXPERIMENTS

No field experiments are located in Harrison County but a number have been under way in other counties for a period of years and as these tests are located on soil types which are the same as those occurring in Harrison County, the results will be given in this report. The tests indicate quite definitely, the results which may be secured on the same soil types in this county. Experiments on the Marshall silt loam on the Avoca Field in Pottawattamie County, on the same soil type on the Red Oak Field in Montgomery County and on the Villisca Field in Montgomery County, on the Waukesha silt loam on the Clarinda Field in Page County and on the Lamoure silty clay loam on the Everly Field in Clay County are included.

The experiments are planned to determine the value of various soil treatments for each particular soil type. The fields include 13 plots, 155 feet 7 inches by 29 feet, 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 plots 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 as the basic treatment, while in the latter crop residues are employed to supply the organic matter. The other fertilizing materials tested include limestone, rock phosphate, superphosphate, muriate of potash, 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 in plowing under the corn stalks which have been cut with a disc or stalk cutter, and plowing under at least the second crop of clover. Sometimes the first crop of clover is cut and allowed to remain on the land to be plowed under with the second. Lime is applied in sufficient amounts to neutralize the acidity of the soil. Rock phosphate is added at the rate of 1,000 pounds per acre once in a four-year rotation. Until 1925 this material was applied at the rate of 2,000 pounds per acre once in four years. Superphosphate is applied at the rate of 150 pounds per acre annually three years out of a four-year rotation. Until 1923 this material was applied at the rate of 200 pounds per acre annually. Until 1923 the old standard 2-8-2 complete commercial fertilizer was used, being applied at the rate of 300 pounds per acre annually. The new standard 2-12-2 brand is now being employed, the applications being made at the rate of 202 pounds per acre annually, thus applying the same amount of phosphorus that is contained in the superphosphate. Muriate of potash is applied at the rate of 50 pounds per acre.

## THE AVOCA FIELD

The results secured on the Marshall silt loam on the Avoca Field in Pottawattamie County are given in table XIII. The beneficial effect of manure on this soil is shown in practically all cases. The influence on the oats may be noted particularly and also the large effects on the clover and sweet clover. The corn yield in 1926 was greatly increased by the addition of manure. In other years the effects on the corn were much smaller. The influence of lime was evidenced

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

| Plot No. | Treatment | 1) 1919 Corn bu. per A. | (2) 1920 Oats bu. per A. | (3) 1921 Clover tons per A. | (4) 1922 Corn bu. per A. | 1923 Oats bu. per A. | 1924 Sweet Clover tons per A. | (5) 1925 Corn bu. per A. | 1926 Corn bu. per A. | 1927 Oats bu. per A. | 1928 Corn bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 72.9 | 62.2 | 2.0 | 58.1 | 48.7 | 0.36 | 62.2 | 54.6 | 45.7 | 64.5 |
| 2 | Manure | 72.1 | 69.0 | 2.7 | 53.6 | 56.7 | 0.63 | 63.9 | 63.7 | 56.0 | 67.5 |
| 3 | Manure+lime | 74.0 | 72.3 | 2.6 | 53.9 | 53.2 | 1.82 | 61.6 | 64.0 | 64.0 | 68.3 |
| 4 | Manure+lime+rock phosphate | 77.8 | 58.8 | 2.7 | 55.5 | 60.0 | 1.52 | 58.1 | 61.3 | 69.8 | 66.4 |
| 5 | Manure+lime+superphosphate | 79.3 | 69.0 | 2.5 | 56.5 | 60.0 | 1.68 | 52.3 | 64.8 | 75.0 | 70.9 |
| 6 | Manure+lime+complete commercial fertilizer | 77.5 | 61.2 | 2.8 | 57.5 | 66.8 | 1.92 | 51.4 | 65.6 | 79.1 | 65.6 |
| 7 | Check | 71.5 | 56.8 | 2.0 | 44.8 | 47.6 | 0.85 | 39.8 | 61.0 | 50.0 | 64.3 |
| 8 | Crop residues | 78.9 | 63.9 | 2.0 | 44.8 | 49.8 | 0.90 | 51.0 | 66.4 | 57.1 | 66.7 |
| 9 | Crop residues+lime | 80.7 | 68.1 | 2.1 | 50.0 | 56.7 | 1.92 | 58.7 | 64.5 | 66.7 | 66.4 |
| 10 | Crop residues+lime +rock phosphate | 78.5 | 68.6 | 2.8 | 54.8 | 59.0 | 1.83 | 56.8 | 69.6 | 66.6 | 62.1 |
| 11 | Crop residues+lime +superphosphate | 81.1 | 75.1 | 2.2 | 54.1 | 64.5 | 1.50 | 57.1 | 66.6 | 64.7 | 66.1 |
| 12 | Crop residues+lime +complete commercial fertilizer | 80.4 | 68.6 | 2.9 | 52.0 | 52.1 | 1.44 | 58.4 | 65.8 | 70.0 | 64.8 |
| 13 | Check | 80.0 | 68.6 | 2.2 | 46.3 | 50.9 | 1.12 | 51.8 | 60.8 | 60.6 | 61.6 |

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.
5. Strong winds and wireworms cut down stand considerably.

particularly on the sweet clover crop in 1924, where a very large increase in yield resulted from its application. There was also an effect noted on the oats in 1927. No beneficial effects were shown on the clover crop in 1921.

Rock phosphate and superphosphate with manure and lime showed large beneficial effects on the crops grown in some seasons. The corn in 1919, 1922 and 1928 showed pronounced effects from superphosphate, and slightly less effects from rock phosphate. There was considerable increase from both phosphates on the oats in 1923 and a large effect in 1927. The crop in 1920 was not matecially benefited. No effects from the phosphates were evident on the clover crops in 1921 and 1924. The complete commercial fertilizer had about the same effect as the phosphates on most of the crops grown. In some cases the complete fertilizer showed a slightly larger influence, as on the sweet clover in 1924 and on the oats in 1927. In other years, as on the corn in 1928, there was less influence from this material.

The crop residues treatment showed small effects in several cases but in general the influence was not great. Lime with the crop residues increased the yields of the various crops grown following the application, with the exception of the corn in 1926 and 1928. The largest influence of the lime was evident on the sweet clover in 1924. Considerable increases were noted, however, on the corn in 1922, the oats in 1923 and the corn in 1925. The rock phosphate and the superphosphate increased crop yields in several cases, the effect of the superphosphate being particularly large on the oats in 1920 and 1923. The effects on the corn crop were not large from either of the phosphates. The complete commercial fertilizer had about the same effect as the superphosphate, except for a large increase on the oats in 1927 and a larger increase on the clover in 1921.

These results indicate that the Marshall silt loam will respond very profitably to applications of farm manure and that manure should be applied liberally. The type is generally slightly acid in reaction and additions of lime are very desirable, especially where legumes are to be grown. Sweet clover is particularly sensitive to acidity and if this crop is to be grown, special care should be exercised to insure an adequate content of lime in the soil. The type should certainly be tested for lime and additions should be made if sweet clover or alfalfa are to be grown. Benefits from phosphate fertilizers are noted in several cases, both with manure and lime, and under the grain system of farming with crop residues and lime. The complete commercial fertilizer generally had no greater effect than the superphosphate and hence is not recommended for general use. It will probably prove less economically desirable on the farm than superphosphate. Superphosphate and rock phosphate should be tested on this soil on individual farms to determine their comparative value.

### THE RED OAK FIELD

Results secured on the Red Oak Field on the Marshall silt loam in Montgomery County are given in table XIV. The value of manure to this soil is shown very definitely by the data in this table. Manure increased the yield of winter wheat in 1918; the corn crops were greatly increased in every case; and increases were also noted with the oats in 1921, the winter wheat in 1922 and 1925, the soybeans in 1924 and the alfalfa in 1927 and 1928. Lime was applied to this soil in 1919 and there were some effects of this material on the various crops grown.

TABLE XIV. FIELD EXPERIMENT, MARSHALL SILT LOAM, MONTGOMERY COUNTY, RED OAK FIELD

| Plot No. | Treatment | (1) 1918 Winter Wheat bu. per A. | (2) 1919 Corn bu. per A. | 1920 Corn bu. per A. | (3) 1921 Oats bu. per A. | (4) 1922 Winter Wheat bu. per A. | 1923 Corn bu. per A. | 1924 Soybeans bu. per A. | 1925 Winter Wheat bu. per A. | (5) 1926 Clover tons per A. | (6) 1927 Alfalfa tons per A. | (7) 1928 Alfalfa tons per A. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 13.6 | 52.0 | 56.0 | 28.2 | 13.2 | 54.5 | 11.2 | 10.4 | --- | 1.84 | 3.36 |
| 2 | Manure | 34.1 | 57.2 | 61.6 | 36.9 | 15.5 | 57.8 | 12.4 | 11.6 | --- | 2.20 | 3.70 |
| 3 | Manure+lime | 31.8 | 59.2 | 66.0 | 37.8 | 18.6 | 64.7 | 14.2 | 11.3 | --- | 3.09 | 3.85 |
| 4 | Manure+lime+rock phosphate | 27.7 | 60.0 | 63.0 | 35.6 | 28.6 | 64.6 | 13.7 | 13.6 | --- | 3.57 | 4.67 |
| 5 | Manure+lime+superphosphate | 31.8 | 58.5 | 62.7 | 39.4 | 30.7 | 62.9 | 13.1 | 13.1 | --- | 3.32 | 4.35 |
| 6 | Manure+lime+complete commercial fertilizer | 29.5 | 56.2 | 64.2 | 36.4 | 25.4 | 61.3 | 14.6 | 10.6 | --- | 3.75 | 4.18 |
| 7 | Check | --- | 54.2 | 56.6 | 31.8 | 17.4 | 50.6 | 10.5 | 9.4 | --- | 2.18 | 3.69 |
| 8 | Crop residues | 29.5 | 51.0 | 54.1 | 31.3 | 16.4 | 52.9 | 9.9 | 8.6 | --- | 2.34 | 3.13 |
| 9 | Crop residues+lime | 25.0 | 53.7 | 60.2 | 31.2 | 19.5 | 55.0 | 13.2 | 10.2 | --- | 2.30 | 4.14 |
| 10 | Crop residues+lime+rock phosphate | 18.1 | 57.7 | 59.2 | 35.0 | 23.8 | 55.7 | 12.3 | 13.0 | --- | 2.54 | 4.21 |
| 11 | Crop residues+lime+superphosphate | 27.2 | 53.7 | 61.6 | 36.9 | 22.3 | 52.7 | 12.1 | 11.6 | --- | 2.53 | 4.26 |
| 12 | Crop residues+lime+complete commercial fertilizer | 26.1 | 57.0 | 57.3 | 37.8 | 22.2 | 56.8 | 14.0 | 12.5 | --- | 1.97 | 3.79 |
| 13 | Check | 13.6 | 48.2 | 51.4 | 29.0 | 15.2 | 52.0 | 8.9 | 9.9 | --- | 1.53 | 3.78 |

1. Clover killed and plowed up. Yield on plot 7 an error.
2. 3½ tons lime applied May 15.
3. 2½ tons of lime applied in September.
4. Dry weather killed out clover.
5. Clover stand very poor due to dry weather. Field was plowed and seeded to alfalfa in August.
6. Results of first and second cuttings combined. No results taken on third cutting.
7. Three cuttings.

The largest beneficial effects were shown, as would be expected, on the alfalfa in 1927 and 1928, but increases were also secured on the corn in 1920, the oats in 1921, the wheat in 1922 and the corn in 1923. The soybeans in 1924 also showed a considerable effect of the lime.

Rock phosphate or superphosphate along with the manure and lime often increased yields; increases being noted particularly on the wheat in 1922 and 1925, and on the alfalfa in 1927 and 1928, the influence on the alfalfa being especially large. In some seasons, as in 1919 and 1920, there was very little evidence of beneficial effects from the phosphates. Superphosphate benefited the oat crop in 1921, but the rock phosphate had no effect. The corn in 1923 showed little effect from the addition and the soybeans in 1924 were not benefited. The complete commercial fertilizer had about the same effect as the superphosphate in practically all cases, showing up a little better in one or two instances but in other cases having a lesser effect.

The crop residues treatment had little effect on the crop yields, as would be expected. Lime with the residues brought about increased yields in most cases. The effect was particularly evident on the alfalfa in 1928, on the soybeans in 1924, on the corn in 1920 and on the wheat in 1922 and 1925. The phosphate fertilizers when applied with the crop residues and lime increased crop yields in several instances, the effect being particularly noted on the wheat in 1922 and

1925, and on the alfalfa in 1927 and 1928. The oats were materially benefited in 1921, and the phosphate increased the wheat yields in 1918. No large beneficial effects of the phosphates were shown on the corn either in 1920 or in 1923, but the rock phosphate showed an increase in 1919. The complete commercial fertilizer again had about the same effect as that brought about by the phosphates. In one or two instances the complete fertilizer gave larger effects, as for example on the soybeans in 1924, on the corn in 1923, and on the oats in 1921; but in other cases, as with the alfalfa in 1927 and 1928, and the corn in 1920, the influence of the complete fertilizer was less than that of the phosphates.

These results confirm those secured on the Avoca Field on the same soil type and indicate the value of manure and lime, and in many cases the possible profit which may result from the application of a phosphate fertilizer. It seems that lime is of particular value on this soil when it is acid if legumes are to be grown. The effect of phosphate fertilizers may be very large in the case of some crops in the rotation and the influence may be exerted on all the crops grown. Tests on individual farms are very desirable to determine the value from the use of a phosphorus carrier.

## THE VILLISCA FIELD

The results secured on the Marshall silt loam on the Villisca Field in Montgomery County are given in table XV. Manure increased the crop yields every year, as shown in the table. Large increases were noted on the clover in 1918

TABLE XV. FIELD EXPERIMENT, MARSHALL SILT LOAM, MONTGOMERY COUNTY, VILLISCA FIELD

| Plot No. | Treatment | (1) 1918 Clover tons per A. | (2) 1919 Corn bu. per A. | 1920 Oats bu. per A. | 1921 Clover tons per A. | 1922 Corn bu. per A. | 1923 Corn bu. per A. | (3) 1924 Corn bu. per A. | (4) 1925 Oats bu. per A. | (5) 1926 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 1.0 | 49.3 | 46.2 | 0.73 | 64.1 | 37.7 | ---- | 15.0 | --- |
| 2 | Manure | 1.2 | 51.0 | 52.1 | 0.88 | 73.9 | 38.8 | ---- | 15.6 | --- |
| 3 | Manure+limestone | 1.3 | 50.3 | 52.7 | 0.99 | 76.6 | 43.2 | ---- | 16.3 | --- |
| 4 | Manure+limestone+rock phosphate | 1.5 | 52.0 | 54.7 | 1.12 | 81.1 | 44.1 | ---- | 18.2 | --- |
| 5 | Manure+limestone+superphosphate | 1.4 | 49.0 | 72.7 | 0.80 | 80.3 | 45.3 | ---- | 17.6 | --- |
| 6 | Manure+limestone+complete commercial fertilizer | 1.6 | 48.7 | 58.1 | 1.04 | 82.4 | 45.8 | ---- | 18.1 | --- |
| 7 | Check | 1.6 | 52.0 | 49.3 | 0.93 | 63.3 | 38.0 | ---- | 14.3 | --- |
| 8 | Crop residues | 1.5 | 49.3 | 47.9 | 0.91 | 63.3 | 37.9 | ---- | 16.5 | --- |
| 9 | Crop residues+limestone | 1.6 | 48.7 | 51.3 | 0.98 | 65.7 | 39.1 | ---- | 13.4 | --- |
| 10 | Crop residues+limestone +rock phosphate | 1.7 | 48.3 | 52.4 | 0.61 | 66.8 | 41.9 | ---- | 14.3 | --- |
| 11 | Crop residues+limestone +superphosphate | 1.6 | 53.0 | 59.7 | 0.83 | 67.3 | 42.3 | ---- | 12.5 | --- |
| 12 | Crop residues+limestone +complete commercial fertilizer | 1.5 | 51.7 | 62.8 | 0.91 | 73.1 | 43.1 | ---- | 16.0 | --- |
| 13 | Check | 1.5 | 55.7 | 51.4 | 0.70 | 64.9 | 36.6 | ---- | 14.3 | --- |

1. Very non-uniform stand of clover.
2. Very uneven stand of corn
3. Crop failure on account of adverse weather conditions.
4. Poor oats on account of drouth.
5. Field discontiuued, farm changed hands.

and on the corn in 1922. Lime was not applied to this field until the fall of 1920. In the succeeding years the effect of lime was evidenced on the clover and the corn crops. Evidently the soil needed lime in order to yield the largest crops.

Rock phosphate or superphosphate with manure and lime increased the crop yields in practically all cases, the gain being definitely evident on the clover in 1918 and on other crops grown later. Rock phosphate showed an effect on the same crop in 1921, but superphosphate did not show up that year. In 1920 the superphosphate showed a particularly large effect on the oats and both phosphates increased the yield in 1925. In 1922 and 1923 the effects of the two phosphates were similar on the corn crops, increases being secured in both cases. The complete commercial fertilizer gave somewhat better effects from the phosphates in one or two cases, notably on the clover in 1918 and the corn in 1922. In other seasons the commercial fertilizer was a little better than the superphosphate; occasionally it was less effective than the rock phosphate.

Very little influence from the crop residues was evident in the yields of the various crops. Lime with the residues increased the crops in 1921, 1922 and 1923. The differences were small but definite. The rock phosphate and superphosphate increased crop yields in practically all cases, with the exception of the clover in 1921. The differences were small, however, except in one or two cases. The corn in 1919 and the oats in 1920 were considerably influenced by the superphosphate, while the rock phosphate had little effect. In 1922 and 1923 the superphosphate was slightly better than the rock, but the differences were not large in either case. Neither material had any effect in 1925. The complete commercial fertilizer with the lime and crop residues had a somewhat greater effect than the superphosphate in three or four cases. The differences were not large except on the corn in 1922. The commercial fertilizer was more effective than the superphosphate on the oats in 1920 and in 1925 and less effective than the phosphate on the clover in 1918 and on the corn in 1919.

The results secured on this field are very similar to those obtained on the two fields previously discussed, and apparently the needs of the Marshall silt loam are very much the same thruout the areas in which it occurs. It is recommended that liberal applications of farm manure be made to this type, that lime be applied when the soil is acid and legumes are to be grown, and that superphosphate be tested on small areas on individual farms to determine its economic value. Complete commercial fertilizers are not recommended for general use at the present time, for superphosphate seems to be as effective and much less expensive.

### THE CLARINDA FIELD

The results secured on the Waukesha silt loam on the Clarinda Field, Series 100, in Page County are given in table XVI. Manure definitely increased yields in most cases on this field, especially of the the clover in 1917 and of the corn in 1922, 1923 and 1927. In one or two cases no increases in yields were secured. Lime applied with the manure benefited practically all of the crops grown. The clover in 1917 and 1925 was benefited very materially, but considerable increases were also noted in the oats and corn in some seasons. A very large increase was secured in the oats in 1916 and 1920 and 1924, and particularly in the oats in 1928.

Rock phosphate or superphosphate with manure and lime proved of consid-

TABLE XVI. FIELD EXPERIMENT, WAUKESHA SILT LOAM, PAGE COUNTY, CLARINDA FIELD, SERIES 100

| Plot No. | Treatment | 1915 Corn bu. per A. | 1916 Oats bu. per A. | 1917 Clover tons per A. | (1) 1918 Corn bu. per A. | 1919 Corn bu. per A. | 1920 Oats bu. per A. | 1921 Soy-beans bu. per A. | 1922 Corn bu. per A. | 1923 Corn bu. per A. | 1924 Oats bu. per A. | 1925 Clover tons per A. | 1926 Corn bu. per A. | 1927 Corn bu. per A. | 1928 Oats bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 51.2 | 61.1 | 1.19 | ---- | 55.1 | 51.0 | 23.5 | 79.4 | 65.9 | 55.6 | 1.45 | 41.0 | 45.6 | 61.2 |
| 2 | Manure | 49.9 | 54.4 | 1.36 | ---- | 58.7 | 52.3 | 25.3 | 87.4 | 73.7 | 53.4 | 1.48 | 42 6 | 53.7 | 52.3 |
| 3 | Manure+limestone | 50.6 | 63.3 | 1.56 | ---- | 62.6 | 61.8 | 25.2 | 89.6 | 73.6 | 61.3 | 1.53 | 42 5 | 55.1 | 74.9 |
| 4 | Manure+limestone+rock phosphate | 48.2 | 50.0 | 2.89 | ---- | 69.3 | 63.6 | 24.2 | 87.9 | 82.1 | 53.7 | 1.41 | 44.4 | 53.2 | 77.1 |
| 5 | Manure+limestone+superphosphate | 54.8 | 52.2 | 3.40 | ---- | 70.9 | 60.4 | 24.3 | 88.3 | 78.0 | 56.7 | 1.31 | 44.0 | 53.9 | 72.6 |
| 6 | Manure+limestone+complete commercial fertilizer | 49.7 | 50.0 | 2.55 | ---- | 59.7 | 73.5 | 23.3 | 90.8 | 76.7 | 66.0 | 1.41 | 42.6 | 53.9 | 84.0 |
| 7 | Check | 48.0 | 47.7 | 1.36 | ---- | 56.3 | 41.8 | 24.0 | 82.4 | 64.6 | 46.5 | 1.50 | 40.9 | 31.5 | 61.2 |
| 8 | Crop residues | 45.2 | 41.1 | 1.53 | ---- | 56.5 | 55.7 | 23.0 | 71.8 | 53.8 | 61.4 | 1.74 | 41.4 | 46.4 | 63.5 |
| 9 | Crop residues+limestone | 51.4 | 43.3 | 2.21 | ---- | 58.2 | 58.7 | 25.8 | 81.2 | 48.6 | 49.0 | 1.81 | 43.7 | 52.3 | 65.9 |
| 10 | Crop residues+limestone+rock phosphate | 51.6 | 47.7 | 2.71 | ---- | 66.7 | 61.1 | 25.8 | 85.2 | 54.5 | 52.7 | 1.65 | 42.9 | 57.2 | 70.4 |
| 11 | Crop residues+limestone+superphosphate | 53.4 | 54.4 | 2.89 | ---- | 69.8 | 60.4 | 24.8 | 87.5 | 57.2 | 54.1 | 1.71 | 42.5 | 54.7 | 68.1 |
| 12 | Crop residues+limestone+complete commercial fertilizer | 50.3 | 47.7 | 2.72 | ---- | 65.3 | 62.4 | 24.8 | 90.[illegible] | 70.1 | 58.8 | 1.50 | 41.6 | 50.9 | 77.1 |
| 13 | Check | 50.5 | 47.7 | 1.36 | ---- | 57.2 | 42.5 | 22.5 | 88.[illegible] | 71.8 | 43.9 | 1.49 | 41.3 | 45.5 | 72.6 |

1. Hot winds seriously damaged corn crop.

erable value to the crops grown in most cases. The influence was particularly great on the clover in 1917, and on the corn in 1919 and 1923. In some seasons, however, only small increases were secured and in several cases no increases at all were obtained. The complete commercial fertilizer had a greater effect than superphosphate in several seasons, particularly on the oats in 1920, 1924 and 1928. Generally, however, the superphosphate was just as, or even more, effective than the complete fertilizer.

Crop residues showed little effect on the various crops, except on the oats in 1920 and 1924 and on the corn in 1927, when rather considerable increases were secured. Lime in addition to the residues proved of value on practically all of the crops. Very large increases were noted on the clover in 1917, on the corn in 1922, and in 1927; and increases were found also in many other cases. Rock phosphate or superphosphate with lime and crop residues increased the crop yields in many cases. A large beneficial effect was noted from both materials on the clover in 1917, on the oats in 1916, 1924 and 1928, and on the corn in 1919, 1922, 1923 and 1927. In most cases the superphosphate showed up much better than the rock phosphate, particularly on the oats in 1916, on the clover in 1917 and on the corn in 1923. In other cases the effects of the two materials were quite similar.

The results secured in this field experiment indicate the value of applications of farm manure, lime and a phosphate fertilizer to the Waukesha silt loam.

Manure is of particular value and large increases in crop yields result from its use. Lime should be applied with the manure if the soil is acid, and considerable gains in yields of legume crops will follow its application. When applied with manure and lime, superphosphate seemed somewhat superior to rock phosphate in many seasons, but usually the differences were not large and in some cases the rock phosphate gave almost as large effects. It is apparent that one or the other of these two phosphates will prove of value on this soil type under the livestock system of farming. Under the grain system of farming, the use of lime is quite as desirable as on the livestock farm, and here the use of the superphosphate seems somewhat preferable.

The results secured on the Waukesha silt loam on the Clarinda Field, Series 200, are given in table XVII. The beneficial effects of manure were evident on this soil type in practically all seasons and very large increases were secured in the case of the corn crop in 1920, 1923 and 1927. The oats showed a large increase in 1925. In one or two cases no increases were secured with the use of manure, undoubtedly due to some abnormal conditions in connection with the crop growth on the manure treated plots. The addition of lime with the manure gave increases in practically all seasons. A large effect was noted on the clover in 1926, on the oats in 1917 and 1921, and small gains were evidenced on practically all of the corn crops.

TABLE XVII. FIELD EXPERIMENT, WAUKESHA SILT LOAM, PAGE COUNTY, CLARINDA FIELD, SERIES 200

| Plot No. | Treatment | 1916 Corn bu. per A. | 1917 Oats bu. per A. | (1) 1918 Clover tons per A. | 1919 Corn bu. per A. | (2) 1920 Corn bu. per A. | 1921 Oats bu. per A. | 1922 Hubam Clover tons per A. | 1923 Corn bu. per A. | 1924 Corn bu. per A. | 1925 Oats bu. per A. | (4) 1926 Clover tons per A. | (5) 1927 Corn bu. per A. | (6) 1928 Corn bu. per A. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 73.1 | 83.0 | 1.8 | 52.2 | 54.3 | 49.2 | ---- | 70.0 | 31.2 | 35.2 | 1.87 | 40.9 | 62.8 |
| 2 | Manure | 77.1 | 83.0 | 1.4 | 56.0 | 64.4 | 32.6 | ---- | 79.3 | 41.8 | 46.6 | 0.86 | 60.1 | 62.3 |
| 3 | Manure+limestone | 78.2 | 88.0 | 1.2 | 57.3 | 65.0 | 60.8 | ---- | 82.4 | 44.7 | 48.5 | 1.28 | 63.9 | 59.8 |
| 4 | Manure+limestone+rock phosphate | 74.9 | 91.1 | 1.8 | 60.9 | 65.9 | 45.8 | ---- | 87.4 | 39.4 | 47.2 | 1.64 | 60.3 | 67.7 |
| 5 | Manure+limestone+super phosphate | 75.9 | 103.6 | 1.5 | 64.5 | 60.9 | 40.2 | ---- | 86.6 | 40.0 | 48.8 | 1.00 | 62.0 | 61.3 |
| 6 | Manure+limestone+complete commercial fertilizer | 80.2 | 98.0 | 1.7 | 61.5 | 62.2 | 52.0 | ---- | 83.1 | 28.1 | 53.7 | 0.95 | 50.3 | 63.6 |
| 7 | Check | 76.7 | 74.8 | 2.3 | 55.0 | 54.8 | 43.4 | ---- | 79.2 | 24.4 | 37.9 | 1.51 | 42.1 | 56.6 |
| 8 | Crop residues | 78.9 | 73.0 | 2.0 | 54.0 | 58.8 | 45.6 | ---- | 73.8 | 24.1 | 39.7 | 1.55 | 49.7 | 58.1 |
| 9 | Crop residues+limestone | 77.5 | 77.8 | 1.8 | 65.7 | 60.0 | 44.8 | ---- | 69.6 | 31.7 | 39.6 | 1.34 | 61.2 | 61.3 |
| 10 | Crop residues+limestone +rock phosphate | 75.8 | 101.0 | 1.7 | 72.7 | 62.1 | 53.9 | ---- | 70.2 | 26.2 | 40.1 | 1.50 | 62.8 | 64.9 |
| 11 | Crop residues+limestone +superphosphate | 76.6 | 100.3 | 1.7 | 72.8 | 61.1 | 52.4 | ---- | 63.6 | 26.6 | 45.2 | 1.33 | 57.1 | 69.9 |
| 12 | Crop residues+limestone +complete commercial fertilizer | 74.4 | 91.6 | 1.4 | 70.8 | 43.7 | 54.1 | ---- | 69.6 | 25.4 | 46.1 | 1.38 | 37.6 | 57.8 |
| 13 | Check | 74.6 | 68.1 | 1.3 | 58.6 | 44.8 | 48.4 | ---- | 62.8 | 20.6 | 36.3 | 1.12 | 33.1 | 50.2 |

1. Plots varied in amount of growth due to moisture conditions.
2. Poor drainage on plots 12 and 13.
3. Stand failed due to dry weather.
4. Uneven stand due to large amount of weeds on some plots.
5. Poor stand on plots 1, 7, 8, 12 and 13 due to poor drainage.
6. Unable to harvest uniform stand due to the listing of the corn.

Rock phosphate or superphosphate, increased crop yields in most cases, particularly the clover in 1918 and 1926, the oats in 1917 and the corn in 1919, 1923 and 1928. In several instances the superphosphate proved superior to the rock phosphate, as with the oats in 1917, but in other instances the rock phosphate gave slightly larger yields than those brought about by the superphosphate.

The complete commercial fertilizer brought about crop increases very similar to those occasioned by the use of the phosphates. In some instances the gains were larger and in a few cases the increases were not quite so great. There does not seem to be any pronounced superiority for the complete commercial fertilizer over the use of a phosphate.

The crop residues increased crop yields to a limited extent in several seasons. The differences, however, were small. Limestone with the crop residues greatly increased the corn in 1919, 1924 and in 1927, and also the oats in several seasons.

Rock phosphate or superphosphate with the crop residues and limestone increased crop yields in most seasons. The largest benefits were evidenced on the oats in 1917, altho gains were also noted in 1921 and 1925. The corn showed pronounced benefits in 1919 and in 1928, but in general the increases were not large. There seems no possible choice between the two phosphates under the grain system of farming, as the increases in yields were very similar from the use of the two materials.

The complete commercial fertilizer gave crop yields which in most cases were very similar or slightly lower than those brought about by the superphosphate. Certainly there is no evidence from the data to show any superiority for the complete commercial fertilizer over the phosphates.

The results as a whole confirm those secured on Series 100 on this same field. They indicate the value of applications of farm manure to this soil. They show the desirability of applying lime, especially if legumes are to be grown. A phosphate fertilizer may be very desirable, at least in some seasons. Tests of rock phosphate and superphosphate are strongly recommended.

## THE EVERLY FIELD

Results secured on the Lamoure silty clay loam on the Everly Field in Clay County are given in table XVIII. The value of farm manure to this soil type is definitely shown, large increases in crop yields being secured almost every season. Beneficial effects were very large with the corn in 1924, the oats in 1922 and 1926, the clover in 1923 and the alfalfa in 1927 and 1928. Superphosphate and the muriate of potash with the manure (the application being made for the first time to this plot in 1921) benefited the crops in practically all cases. Increased crop yields were noted on the clover in 1923, on the oats in 1927 and 1928, on the corn in 1924 and on the oats in 1922 and 1926.

Rock phosphate or superphosphate with the manure increased yields in most seasons, particularly the clover in 1919 and 1923 and the alfalfa in 1927 and 1928. The oats were also materially benefited by the phosphates in 1922 and 1926, and the corn was greatly increased in 1924. In the other seasons when corn was grown no large effects of the phosphates were shown. The superphosphate showed up much better than the rock phosphate on the clover crop and on the alfalfa. It also proved more beneficial on the oats. The complete commercial fertilizer applied with the manure showed smaller effects than the superphos-

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

| Plot No. | Treatment | 1919 Clover tons per A. | 1920 Corn bu. per A. | *1921 Corn bu. per A. | 1922 Oats bu. per A. | 1923 Clover tons per A. | 1924 Corn bu. per A. | 1925 Corn bu. per A. | 1926 Oats bu. per A. | (1) 1927 Alfalfa tons per A. | (2) 1928 Alfalfa tons per A. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Check | 1.45 | 74.6 | 65.8 | 35.6 | 0.57 | 31.8 | 57.9 | 47.4 | 1.05 | 2.03 |
| 2 | Manure | 1.45 | 83.2 | 75.3 | 54.1 | 0.71 | 58.2 | 68.6 | 62.9 | 1.43 | 2.94 |
| 3 | Manure+superphosphate +potassium | 1.60 | 83.2 | 75.8 | 70.4 | 1.83 | 69.4 | 58.8 | 76.8 | 2.82 | 4.71 |
| 4 | Manure+rock phosphate | 1.67 | 83.2 | 70.0 | 64.1 | 1.25 | 61.7 | 55.1 | 76.8 | 1.82 | 4.54 |
| 5 | Manure+superphosphate | 2.03 | 80.8 | 68.1 | 70.2 | 1.75 | 67.2 | 55.8 | 83.0 | 3.26 | 5.31 |
| 6 | Manure+complete commercial fertilizer | 1.79 | 80.8 | 63.2 | 68.4 | 1.26 | 60.8 | 54.0 | 71.1 | 3.00 | 4.82 |
| 7 | Check | 1.68 | 66.9 | 54.5 | 58.3 | 0.77 | 43.2 | 44.0 | 54.7 | 1.22 | 2.61 |
| 8 | Crop residues | 1.56 | 70.4 | 54.7 | 52.8 | 0.87 | 39.6 | 43.4 | 53.4 | 1.02 | 2.76 |
| 9 | Crop residues+superphosphate+potassium | 1.56 | 70.4 | 61.9 | 61.1 | 1.47 | 56.5 | 44.2 | 71.6 | 2.26 | 4.22 |
| 10 | Crop residues+rock phosphate | 1.68 | 73.6 | 60.4 | 57.7 | 1.14 | 61.2 | 42.2 | 72.4 | 1.24 | 3.55 |
| 11 | Crop residues+superphosphate | 1.56 | 83.4 | 60.8 | 62.8 | 1.59 | 57.7 | 44.7 | 77.6 | 2.28 | 3.99 |
| 12 | Crop residues+complete commercial fertilizer | 2.03 | 77.8 | 64.7 | 78.4 | 1.73 | 56.4 | 57.7 | 76.5 | 2.72 | 4 37 |
| 13 | Check | 1.62 | 61.2 | 54.0 | 48.5 | 0.83 | 35.7 | 53.5 | 50.4 | 1.00 | 2.04 |

* Superphosphate and potassium added to plots 3 and 9.
(1) Total of 2 cuttings.
(2) Total of 3 cuttings.

phate in all seasons. The complete commercial fertilizer is not as desirable for use on this soil as the superphosphate. Muriate of potash with the superphosphate on plot 3 did not show any pronounced benefits over the use of the superphosphate alone on plot 5. In fact, in most cases there was no indication of value from the use of the potash.

The crop residues slightly increased crop yields in several seasons, but the increases were not significant. Rock phosphate or superphosphate used with the crop residues increased crop yields in most seasons. In come cases the gains were very large, as on the clover in 1923, and on the alfalfa in 1927 and 1928. Increases were also noted on the oats and on the corn in several seasons. In most instances the superphosphate showed up very much better than the rock phosphate on the various crops grown on this field. The difference is particularly notable on the alfalfa, on the clover in 1923, on the oats in 1922 and 1926 and on the corn in 1920. The superphosphate and muriate of potash applied with the crop residues brought about increases very similar to those occasioned by the use of the superphosphate alone. Only with the alfalfa in 1928 was there any pronounced difference in yield in favor of the muriate of potash with the superphosphate over the superphosphate alone. The complete commercial fertilizer with the residues increased the yields in practically all seasons, and in some cases the increases were very large. Large beneficial effects were noted on the clover in 1919 and 1923, and on the alfalfa in 1927 and 1928. On all these crops the complete fertilizer gave larger increases than did the superphosphate. It also proved more effective on the oats in 1922 and on the corn in

1921 and 1925. In the other cases the differences were not large but were slightly in favor of the phosphate. From these data there is some evidence of superiority for the commercial fertilizer over superphosphate on this soil at least in some seasons, but owing to the higher cost of the complete fertilizer it is doubtful whether crop increases would prove as economical as those brought about by the superphosphate.

It is apparent from the data secured on this field that the Lamoure silty clay loam will respond to small applications of farm manure. Large amounts should not be applied, particularly preceding the growing of a small grain crop, as the manure is likely to cause the grain to lodge. A phosphate fertilizer is very desirable on this soil and the evidence is very strong that superphosphate will bring about larger crop increases than will the rock phosphate on this type. Complete commercial fertilizers are probably not as desirable as a phosphate on this soil. There is no evidence of large value from the use of muriate of potash in addition to superphosphate.

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

The general needs of the soils of Harrison County have been indicated quite definitely by the results of the laboratory, greenhouse and field experiments which have been discussed in previous pages. Some recommendations may, therefore, be given here which will be applicable to the county as a whole. Altho the field experiments described in this report have been carried out in other counties, the soil types are the same as those occurring in Harrison County, and hence the results indicate quite definitely the effects of the same fertilizer treatments. The recommendations which are offered here are based not only upon the experiments which have been discussed but also upon the general experience of many farmers. No suggestions are made except those which have been shown to be of value by much practical experience and any of the recommendations may be put into effect on any farm.

In a number of cases it is suggested that tests be carried out on individual farms and it may be noted that many farmers are already carrying out simple tests of fertilizing materials and securing data of considerable value to themselves and to farmers on the same soil type. Such tests are easily planned and carried out. The Soils Section of the Iowa Agricultural Experiment Station is ready to aid any farmers who may be interested in conducting tests on their own soils.

### Manuring

Most Harrison County soils are fairly well supplied with organic matter and in the case of some of the heavier bottomland soils the content of organic matter is high. In some of the types, however, and particularly in the more extensively developed upland soils, there is no large content of organic matter and the addition of fertilizing materials supplying this constituent is very desirable. It is particularly important on these soils that some method be followed for the return of organic matter in order to insure the maintenance of fertility.

The most important means of supplying organic matter is by the application of farm manure. It is undoubtedly the most valuable fertilizing material which can be employed, and its value is due largely to the addition of organic matter. Large crop increases are secured from the use of farm manure on the upland soils of this county and on many of the bottomland types it brings about considerable increases in the yields of general farm crops. Its value has been noted particularly on the Marshall silt loam, the Knox silt loam, the Carrington loam, the Waukesha silt loam and the Lamoure silty clay loam. All of the other terrace types will likewise respond to additions of farm manure, and on the other bottomland types, particularly those which are light in color and sandy in texture, the use of manure is very desirable. On the heavier black soils it should be applied only in small quantities but even on these types small applications are frequently much worth while because of the stimulation they bring about in the production of available plant foods. On such types the application of even small amounts of farm manure should not be made preceding the growing of a small grain crop.

The growing and turning under of a legume crop for green manuring purpurposes is very desirable on many of the upland soils in this county. On grain farms where little or no farm manure is produced, green manuring is essential in order to build up and maintain the supply of organic matter and nitrogen in the soil. On many livestock farms the production of farm manure is inadequate to supply the needs of all the land and hence green manuring must be resorted to to make up the deficit. On many farms green manuring is desirable as a substitute for or to supplement farm manuring. Legumes should be used for green manuring rather than non-legumes because it is possible by growing well inoculated legumes to utilize nitrogen from the atmosphere. Thus the nitrogen content of the soil may be increased when the crop is turned under. Green manuring may be practiced to considerable advantage on the Marshall silt loam, the Knox silt loam and the Carrington loam on the uplands. Green manuring should not be followed carelessly, however, as undesirable results may occur if the conditions are not satisfactory for the best decomposition of the green material.

The utilization of all the crop residues on the farm is an important aid in the maintenance of the organic matter content of the soil. If the residues are burned or otherwise destroyed, as is often done, there is a considerable loss of valuable fertilizing constituents. On the livestock farms the residues may be used for bedding and returned to the land with the manure. On the grain farms crop residues may be stored and allowed to decompose partially before being applied, or they may be applied directly to the land. Under both systems the thoro utilization of the residues is strongly to be recommended.

### The Use of Commercial Fertilizers

The phosphorus supply in the soils of Harrison County is rather low, and phosphorus fertilizers will soon be needed on these soils if crop yields are to continue to be satisfactory. There are indications, however, that profitable results may be secured at the present time from the use of phosphate fertilizers. Greenhouse and field experiments which have been discussed in this report have indicated considerable increases in crop yields in many cases from the use of phosphate fertilizers.

The two phosphorus carriers which may be used as phosphate fertilizers are rock phosphate and superphosphate. The latter supplies the element phosphorus in a form which is immediately available for plant food. Rock phosphate, on the other hand contains the element in a form which is only slowly made availab. in the soil. Superphosphate is more expensive but is applied in smaller amounts, usually at the rate of 150 to 200 pounds per acre annually. Rock phosphate is applied only once in a four-year rotation at the rate of about 1,000 pounds per acre. In some cases the superphosphate seems to give much better results but in other instances the rock phosphate shows up quite as well. In general quicker effects may be expected from the use of the superphosphate while the rock phosphate does not show its largest influence until the second or third year following application. Furthermore, on soils low in organic matter, superphosphate is much more desirable, while on soil types well supplied with organic matter the rock phosphate may prove quite as profitable. To determine the response of the soil to a phosphorus fertilizer, it is very desirable that an application of superphosphate be made. When the phosphorus need of the soil has been shown by means of this material, then tests may be carried out with both the superphosphate and rock phosphate to determine which will prove more profitable under the particular conditions on the farm. It is very desirable that farmers test these materials under their own conditions and it is recommended that a phosphate fertilizer be tested on many of the soils of this county. Simple tests may be carried out easily on any farm. Directions which may be followed in making such tests are given in Circular 97, of the Iowa Agricultural Experiment Station.

Most of the soils in the county are fairly well supplied with nitrogen and only in one or two cases is there a deficiency. It is very important, however, that some material supplying nitrogen be applied to the soils regularly if the content of the element is to be kept up. The proper preservation and application of all the farm manure produced is very desirable to aid in keeping up the nitrogen content of the soil. On livestock farms, the use of manure will aid materially in preventing a deficiency of nitrogen. However, not all of the nitrogen lost from the land can be returned even thru the best methods of farm manuring. On the livestock farm, therefore, the use of leguminous crops as green manures is very necessary to supplement farm manure as a source of nitrogen. When the legume is inoculated, a large part of the nitrogen which it contains is taken from the atmosphere, and hence when the legume is turned under as a green manure there may be a considerable increase in the nitrogen content of the soil. On grain farms the use of leguminous crops as green manures is very necessary to permi of the maintenance of the nitrogen content in the land. Crop residues also ai to a certain extent in keeping up the nitrogen supply of the soil, and these mate rials should be applied to the land and not burned or otherwise destroyed. Thr the proper utilization of all the crop residues, farm manure and leguminous crop as green manures, it should be possible to keep up the nitrogen in the soils witl out having to resort to the application of commercial nitrogenous fertilizers.

Earlier analyses have shown a large total potassium content in the soils Harrison County, and it is not likely that potassium fertilizers will be needed the present time. If the conditions in the soil are such that there is a rapid pr duction of available potassium, then no response from the use of a potassiu fertilizer will be secured. Proper cultivation and drainage, additions of organic matter and lime and other general soil treatments will aid in the production of available potassium from the supply already present. Potassium fertilizers cannot be recommended for general use on the soils of this county at the present time. If it is desired to test a potash fertilizer, a small amount may be applied and its effect on crop yields determined. Tests of any potash fertilizer should be made on a small area before any extensive application is made.

Complete commercial fertilizers supply nitrogen and potassium as well as phosphorus and their use is very desirable on soils which are lacking in all three of these plant food constituents. It does not seem probable that such complete fertilizers are needed, however, on the soils of Harrison County. Potassium is not likely to be deficient in these soils, and nitrogen may be more cheaply supplied by using a legume as a green manure. Phosphorus is the only element which is almost certain to be deficient and it would seem more desirable to supply this constituent by the use of superphosphate, which is considerably cheaper than the complete fertilizers. The experimental data which have been reported earlier indicate that in most cases practically as large effects may be secured with superphosphate as with the complete commercial fertilizer. Hence the latter cannot be recommended for general use at the present time. Before any complete commercial fertilizer is used extensively on any farm, it should be tested on a limited area to determine the value from the application and especially to determine its relative value in comparison with superphosphate. If profitable effects are secured, then there is no possible objection to the use of a complete fertilizer. It is simply a question of economic returns.

## Liming

The soils in Harrison County are not generally acid in reaction, and the great majority of the types, particularly those on the bottomlands, are well supplied with lime. The Marshall silt loam, however, the most extensively developed upland soil, is slightly acid in reaction in the surface soil and thruout the three-foot section. The Carrington loam on the upland is also acid in reaction. The Knox silt loam, the third upland type is strongly basic in reaction and not in need of lime. On the terraces the Waukesha and Judson soils are slightly acid in reaction but the Hancock type is basic. On the bottomlands, all the soils are basic in reaction and except for the Wabash types show a high content of lime. Only with the Marshall and Carrington soils on the uplands, the Waukesha and Judson types on the terraces and the Wabash types on the bottoms is there a need for lime on the soils of this county. While the extent of acidity is not great, these soils will respond to applications of lime, especially if legumes are to be grown.

The greenhouse and field experiments discussed earlier in this report indicated definitely the value of lime to soil types which are acid in reaction. The experiences of many farmers have also shown the beneficial effects on crop yields of such legumes as alfalfa and sweet clover when lime is applied to the soil. It is very desirable, therefore, that the soil types which have been listed as acid in reaction be tested and the necessary amount of lime be applied, especially before seeding to a legume. Farmers may test their own soils but the test will usually be more satisfactory if a small sample is sent to the Soils Section of the Iowa Agricultural Experiment Station, where it will be tested free of charge and recommendations made regarding treatment. These soils should be tested for lime needs at least once in a four-year rotation, and always before the legume of the rotation is to be grown. In this way it will be possible to keep up the lime content of the soil and insure the most desirable growth of such legumes as alfalfa and sweet clover.

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 Extension Service. A list of companies prepared to furnish lime for agricultural use is also given in the bulletin.

## Drainage

As noted earlier in this report, the natural drainage system on the uplands of this county is excellent and there are very few cases where the upland types are in need of artificial drainage. The various streams with their tributaries and intermittent drainageways extend into practically all parts of the upland and carry away the excess water. Furthermore these types do not have stiff and impervious subsoils and are, therefore, not likely to retain large amounts of water. On the bottomlands, however, which are developed extensively in the western and southwestern parts, the need for artificial drainage is very often evident. The deepening and straightening of the natural drainage channels which flow thru this bottomland area and the laying of tile drains have helped materially to drain large areas. The installation of tile in other areas in the bottomlands is still desirable, however, if drainage is to be entirely satisfactory. The map given earlier in this report indicates the extensive natural drainage system of the upland areas and the lack of natural drainage on the bottomlands.

Soils which are too wet will not produce satisfactory crop yields, and the first treatment needed on some of the soils of Harrison County is adequate drainage. Farmers should drain their land well if they wish to secure the best results. The installation of tile is a rather expensive operation but the results secured warrant the outlay. No fertilizer treatment will bring about profitable returns on land which has not been adequately drained. The practical experience of many farmers shows quite definitely that the benefits from tiling are large and in many cases it may mean the difference between no crop and very satisfactory crop yields.

## The Rotation of Crops

It is a matter of common knowledge that the continuous growing of any one crop will quickly reduce the fertility of the soil and crop yields will decrease rapidly. Even if the crop grown continuously is of especially large money value, it is more profitable, over a period of years, to rotate crops, even if crops of less money value are grown in the rotation. Much experimental evidence supports the value of crop rotation and an abundance of farm experience confirms the experimental data.

No special tests have been carried out in Harrison County to determine the most desirable rotations to be followed. A number of rotations, however, have been used thruout the state for many years and from among these some one may be chosen which will be suitable for use in this county. Modifications of the rotations as suggested may be made to fit the local conditions. In fact almost any rotation may be employed with satisfaction provided it contains a legume and money crops adapted to the area. The following are some of the common rotations in Iowa.

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 rotation)

4. FOUR-YEAR ROTATION

*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 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.

The two types of erosion are 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 less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked, an entire field may soon be made useless for farming purposes.

Erosion occurs to some extent in Harrison County, its effect being particularly noted on the Carrington loam and the Knox silt loam on the upland. There is also considerable washing of the Marshall silt loam in the more rolling areas. Evidently there are many cases in the county where some means of prevention or control of the destructive action of erosion should be adopted.

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

## EROSION DUE TO DEAD FURROWS

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

*"Plowing In"*—It is quite customary to "plow in" the small gullies that result from dead furrows and in level areas this process may be 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 of driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed 3 or 4 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 are 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 2 or 3 feet above the bottom of the gully. A large sized tile should be used 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 the earth dam, such as sorghum, or even oats or rye, and later to 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 drainage-ways 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 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

Large gullies or 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, especially where they are crossed by small streams, and 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 also aid 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 cornstalks may also be turned under to increase the organic matter content.

*Growing Crops*—The growing of crops, such as alfalfa, that remain on 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 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 effective in preventing erosion. This practice is called "contour discing" and has proven 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 HARRISON COUNTY*

There are 21 individual soil types in Harrison County and these with the colluvial phase of the Wabash silt loam, the deep phase of the Sarpy silt loam, the

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

deep phase of the Sarpy silty clay loam and the riverwash make a total of 25 separate soil areas. They are divided into four groups, drift soils, loess soils, terrace soils, and swamp and bottomland soils.

## Drift Soils

### CARRINGTON LOAM (1)

The only drift soil in the county is classified as the Carrington loam. It is of limited occurrence, covering only 0.3 percent of the total area. This type is found in a number of small areas in various parts of the county where the streams have cut thru the loess, exposing the underlying drift material. It occurs in narrow strips on the lower hill slopes which border the stream valleys of many of the rivers and creeks and their larger tributaries. There are no large areas of the type. The Carrington loam is found chiefly along Willow River, Boyer River, Harris Grove Creek, Potato Creek, Pigeon Creek and Mosquito Creek, and particularly along one of the tributaries of the latter creek in Washington Township in the southeastern corner of the county.

The surface soil is a dark grayish-brown loam, extending to a depth of about 6 inches. There is an abrupt transition to the subsoil material which consists of a dark yellowish-brown silty clay loam, extending to a depth of 24 to 30 inches. Below this point is a stiff brown sandy or gravelly clay. The surface material varies considerably in texture, ranging from a silt loam where there has been some wash from the higher areas of Marshall silt loam to a coarse sandy loam where the surface soil has been badly eroded. Coarse sand and gravel and a few small boulders are found in the surface soil and in larger quantities in the underlying soil layers. Many small patches of the type occur which are too small to show on the map. They are included with the areas of Marshall silt loam.

In topography the Carrington loam is generally rolling to rough. In some areas the surface is so rough that it is suitable for pasture purposes only. Drainage is naturally good.

Owing to its small acreage, the Carrington loam is of little agricultural importance. Most of it is cultivated but a few areas are too rough for cultivation and are utilized only for pasture purposes. On these areas there is a limited growth of trees.

When in cultivation, the Carrington loam is particularly in need of additions of organic matter to make it more productive. It is acid in reaction and should be limed for the best growth of general farm crops and particularly of legumes. Additions of a phosphate fertilizer would also undoubtedly prove of value.

## Loess Soils

There are two loess soils in the county, classified in the Marshall and the Knox series. Together they cover 52.5 percent of the total area.

### MARSHALL SILT LOAM (9)

The Marshall silt loam is by far the most extensively developed type in the county, covering over 45.8 percent of the total area. It is found on all the uplands except where the lighter colored Knox silt loam forms a narrow strip along the bluffs of the Missouri Valley, and where the small areas of Carrington loam are exposed.

The surface soil of the Marshall silt loam is a very dark grayish-brown, friable silt loam, appearing almost black when wet. It extends to a depth of about 5 inches. The subsurface layer is similar in color to the surface soil but consists of a slightly heavier silt loam. This layer on the smoother uplands is about 7 inches in thickness. On the slopes the surface soil is thinner and on small areas on the steep slopes, on the tops of sharp knolls and ridges, the darker colored surface soil has been removed and the lighter colored subsoil exposed. On the more level to smooth, broad areas between the streams, the surface soil and subsurface layer will usually amount to about 12 inches.

The upper subsoil of the type is a dark grayish-brown in color, becoming lighter at the lower depths. This layer extends to a depth of from 18 to 25 inches where it grades into a grayish-brown heavy silt loam to a depth of 25 to 35 inches. Below 35 inches the color is a grayish-yellow or yellowish-brown and the soil material is soft and friable. Below this point there is the unweathered, unleached parent loess which consists of a loose, structureless grayish-yellow or yellowish-brown silt. No carbonates are found in the surface layer or thru the 3-foot section. Below 35 to 40 inches or when the unleached parent loess material is reached, there are usually sufficient carbonates present to cause effervescence when the material is tested. In some areas where the surface soil is thin, the soil is much lighter in color than in the typical, more level interstream areas. Narrow strips of this light colored soil are found on the more hilly or rough areas but they are included with the typical soil.

In topography the Marshall silt loam is typically gently undulating to slightly rolling but there is a considerable area of the type where the topography is more hilly to rough. The broad, rather level areas between the streams are typical of the most common topography. Hillier and rougher areas are found in eastern Jefferson Township and in the western part of Harris, LaGrange, Magnolia, Allen and Lincoln townships, and some very hilly areas occur in western Boyer and Jackson Townships. Drainage over practically all of this soil is adequate and on the steeper slopes it is excessive. Here gullies are easily formed and there is considerable erosion.

All of this soil is under cultivation except a few areas on the steeper slopes which are still forested and used for pasture purposes. Corn, oats, alfalfa and sweet clover are the chief crops. Average yields of corn amount to 43 bushels per acre. Oats yield about 30 bushels per acre. Sweet clover and alfalfa are well adapted to the type and excellent yields are secured. Orcharding is practiced rather extensively, and the commercial apple orchards range in size from 5 to 40 acres. Small fruits are grown for local markets and some are shipped to the larger markets. Small truck gardens are found near the towns, and many farm gardens supply the local markets with vegetables. Other minor crops grown include wheat, which is produced to a very limited extent in the southwest corner of the county, sorghum and soybeans.

The Marshall silt loam is normally a rather productive type and yields of general farm crops are fairly satisfactory. By proper methods of management, however, considerable increases in the yields of crops may be secured. The use of farm manure is very desirable on this soil and will bring about large increases in crop yields. The turning under of leguminous crops as green manures has been shown to be of large value and crop yields are materially increased when green manuring is practiced. The type is slightly acid in reaction and the addition of lime is desirable for the best growth of legume crops. The use of a phosphate fertilizer is recommended on this type and may bring about very pronounced increases in crop yields. Either superphosphate or rock phosphate should be used and farmers are urged to test both materials under their farm conditions. In some of the experiments which have been discussed earlier, superphosphate has seemed to be slightly superior to the rock phosphate but in other cases rock phosphate has given as large or even larger returns. It seems evident that some phosphate fertilizer should be used on this soil and it is difficult to determine which material will prove more profitable without actual tests being made under individual farm conditions. Complete commercial fertilizers will probably prove of less value on this soil than superphosphate. While they bring about as large increases in crops in most cases, they are much more expensive and hence the increases secured are less profitable.

### KNOX SILT LOAM (11)

The Knox silt loam is the second largest loess type, but it is very much smaller in extent than the Marshall silt loam, covering only 6.7 percent of the county. The type is developed most extensively along the bluffs which border the Missouri River in the western part of the county. The largest area is 2½ miles in width and 6½ miles long, extending northward from Orson into Monona County. Strips from ¼ mile to 2½ miles wide are found along the Missouri River, separating the upland from the bottomland soils. Similar strips occur, extending along the upland bluffs along Soldier River, Spear, Allen and Stowe Creek and their tributaries. Other small areas of the type occur on the upland ridges adjacent to the steeper drainageways.

The surface soil of the Knox silt loam is a light brown to brown loose, friable silt loam. On the steep slopes where the surface material has been partly removed by erosion, the soil is thin and on very steep slopes and on the tops of knolls and ridges, the surface soil has been entirely removed and the subsoil exposed. The surface soil on the more level areas reaches a depth of 8 or more inches. The average depth is around 5 inches. The subsurface layer consists of a brown to yellowish-brown silt loam, slightly heavier in texture than the surface soil. This layer usually extends to a depth of 12 to 18 inches, but in many of the areas the layer is not present in the soil and the dark surface soil rests directly on the yellowish-brown silt loam of the parent loess. Where the soil is typically developed, the surface soil and the subsurface layer often show no carbonate content, but the lower part of the subsurface soil and the subsoil are always very high in lime, showing many lime concretions. In many of the areas there are streaks of lime and where erosion has occurred and the soil is thin, lime occurs in large amounts near the surface.

There is a variation from the typical soil in a small area which occurs at the low elevation on the Monona-Harrison County line two miles north of Pisgah. Here the material is a silt loam similar to the bottomland silt loam of the Lamoure type, and the surface soil is underlaid by a black silty clay loam mottled with gray and brown. The color of the surface soil varies widely in different areas of the Knox silt loam. On the rougher slopes and ridges the color is lighter but nowhere is the color as dark as that of the Marshall silt loam. Faint gray mottlings sometimes occur in the deeper subsoils and iron stains are frequently found. Pockets of very fine sand or sand occur in a few places in the subsoil, usually at the base of the higher bluffs adjoining the bottomlands.

The topography of the Knox silt loam is generally rolling with many variations up to the hilly to rough or bluff sections. The Knox silt loam is found on gradual slopes and narrow undulating ridge tops and on steeper areas which are too steep for cultivation. Drainage is good and on many slopes erosion has been serious and the soil has been damaged considerably.

About 50 percent of the type is under cultivation; the remainder, including the steeper areas where cultivation is impracticable, is utilized for pasture purposes. Corn is the chief crop grown on the cultivated sections and yields average from 20 to 50 bushels per acre. Alfalfa and sweet clover do very well on this type and yield from two to three tons per acre. Oats yield 20 to 35 bushels per acre. Potatoes are grown on limited acreages and other vegetable crops are occasionally produced. Wheat is grown to a small extent on this type. Grapes and bush and tree fruits, altho grown only in a very limited way seem to be well adapted to the soil. The yields on the type are generally much less than those secured on the Marshall silt loam.

The needs of this soil to make it more productive are chiefly for the incorporation of organic matter and the use of a phosphate fertilizer. Liberal additions of farm manure are very desirable, and large increases in crop yields will follow its use. The turning under of leguminous crops as green manures is also very desirable and will aid materially in building up the fertility of the soil. The use of a phosphate is strongly recommended, and tests of superphosphate on this type are urged.

## Terrace Soils

The three terrace types in the county are classified in the Waukesha, Judson and Hancock series. Together they cover 2.9 percent of the total area of the county.

### WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the largest terrace type, covering 1.6 percent of the total area. It is developed along many of the streams and their tributaries in various parts of the county. The most extensive areas occur along Boyer River from its entrance into the county to the Missouri River bottomland soils in the western part of the county. Smaller areas occur along Willow River and along Soldier River northeast of Orson to the county line. Where it is found along Boyer River it occurs on terraces 5 to 30 feet above overflow. Along Soldier River the soil is 15 to 30 feet above the first bottoms, while along Willow River the type is 5 to 10 feet above overflow.

The surface soil of the Waukesha silt loam is a very dark grayish-brown silt loam, 18 inches in depth. The subsurface layer is a granular silt loam or in places a heavy silt loam, the color changing from a very dark grayish-brown to a brown. At a depth ranging from 24 to 36 inches, there is a layer of a yellowish-brown silty clay loam, about 12 inches in thickness. This is underlaid ordinarily by a sandy material or a material varying considerably in texture. Beds of sand and gravel occur in a few small areas at these lower depths.

A few small areas of a lighter colored soil have been included with the Waukesha silt loam owing to their limited extent. The soil in these patches is calcareous and occurs where the original darker surface materials have been removed by erosion. The town of Calhoun is located on an area of this soil along the Missouri River bottomlands. The total acreage of this light colored soil is less than 100 acres. There are also areas where both the surface soil and the subsoil are calcareaus. It is found in narrow continuous strips from 15 to 200 feet wide on the edge of the terraces and slopes adjoining the first bottoms. The surface soil resembles the Waukesha but is generally thinner and the subsoil is exposed in many places on the steeper slopes adjacent to the stream bottoms. Considerable coarse sand and gravel may also occur along these slopes.

In topography the Waukesha silt loam is level to flat, and the land generally slopes slightly toward the stream channels. The areas vary in width from 200 feet to ¾ of a mile. They are found in continuous strips from ¼ of a mile to 3 miles long. Natural drainage is good except in a few depressions which occur in limited areas.

All of the Waukesha silt loam is under cultivation and the same crops grown on the adjacent uplands of the Marshall silt loam are produced on this type. The yields are similar to those secured on the Marshall silt loam. The treatments needed to make the soil more productive are also similar to those recommended for the Marshall. The incorporation of organic matter is desirable, and liberal additions of farm manure are recommended. The turning under of legume crops as green manures is also very desirable. The type is generally acid in reaction and the addition of lime is necessary for the best growth of a legume. A phosphate fertilizer is recommended for this soil and tests of superphosphate and rock phosphate are urged.

## JUDSON SILT LOAM (131)

The Judson silt loam is a minor type in the county, covering only 1.2 percent of the total area. It is found in several small areas on the terraces along some of the more important streams. The largest areas are in the northeastern corner of the county along the Boyer River south of Dunlap. Here it occurs in bodies from ⅛ of a mile to 2½ miles long and from ⅛ of a mile to ½ mile in width. Small isolated areas are found at the base of the upland slopes along many of the rivers and larger creeks in other parts of the county.

The Judson silt loam surface soil is a very dark grayish-brown friable silt loam, extending to a depth of 15 inches. The subsurface layer is a slightly lighter colored, somewhat heavier silt loam, becoming lighter in color at the lower depths and in some places being faintly mottled with gray. In some depressions the subsoil shows distinct mottlings of gray or brown to a depth of three feet.

In topography the Judson silt loam is level to nearly flat, sloping gently toward the first bottomland into which it grades very gradually. On the more recent deposits along the tributary streams, the areas are gently undulating. Practically all of the type lies well above overflow, and drainage is well established.

All of the Judson silt loam is under cultivation and general farm crops such as are produced on the Marshall silt loam are grown on it. The yields are similar to those secured on the Marshall silt loam. A few areas of the type are in permanent pasture. The needs of this soil are similar to those which have been discussed in the case of the Marshall silt loam. It will respond to applications of farm manure and the turning under of leguminous crops as green manures. The type is slightly acid in reaction and the addition of lime is desirable for the best growth of legumes. The use of a phosphate fertilizer is recommended on this soil, and tests of superphosphate and rock phosphate are urged.

#### HANCOCK FINE SANDY LOAM (214)

The Hancock fine sandy loam is a very minor type in the county, covering only 0.1 percent of the total area. Only three small areas of the soil have been mapped, two in Section 17 of Jefferson Township and one in Section 1 of Jackson Township.

The surface soil of the Hancock fine sandy loam is a dark grayish-brown fine sandy loam, extending to a depth of about 18 inches. Below 18 inches, the subsoil is a brown or yellowish-brown loamy fine sand or sand. The soil is highly calcareous thruout the entire soil section. In a small area in Jackson Township the surface soil is a yellowish-brown fine sandy loam. The type is level in topography and drainage is good to excessive. In dry seasons crops suffer for moisture owing to the sandy texture of the soil and subsoil.

All of the type is under cultivation, but crop yields are much smaller than those secured on the Waukesha silt loam. The type is particularly in need of organic matter to make it more retentive of moisture and hence more productive. Liberal amounts of farm manure should be employed, and the turning under of a leguminous crop as a green manure is strongly recommended. The application of a phosphate fertilizer would also undoubtedly be desirable, and tests of superphosphate are urged.

### Swamp and Bottomland Soils

There are 19 swamp and bottomland soils in the county, including the colluvial phase of the Wabash silt loam, the deep phase of the Sarpy silt loam, the deep phase of the Sarpy silty clay loam and the area of Riverwash. Together they cover 44.4 percent of the total area of the county.

#### LAMOURE SILT LOAM (153)

The Lamoure silt loam is one of the more extensively developed bottomland types. It covers 2.5 percent of the total area and is found in numerous areas in various parts of the county, the largest being developed along Willow River and Soldier River. A number of scattered areas varying widely in size occur in the Missouri River bottomlands.

The surface soil of the Lamoure silt loam is a very dark grayish-brown to black heavy silt loam. The subsoil is a granular, grayish-brown silty clay loam, which below 24 inches varies somewhat in color from a grayish-brown to a dark gray, mottled with yellowish-brown and rusty brown. Below 24 inches the texture is a clay loam to clay. In a few places there are beds or pockets of sand or silt. In practically all of the areas the soil is calcareous thru the entire soil section. In the areas along Willow River and Soldier River the surface soils when dry are somewhat lighter in color than the typical Lamoure types. In many places the subsoil is only slightly heavier than the surface soil. In the large area southwest of Calhoun, there is considerable variation in texture.

In topography the Lamoure silt loam is nearly flat with a slight slope toward the stream channels. Because of the deepening and straightening of Willow

River and Soldier River, there are rough uneven strips along both the old and the new channels. The drainage of the type, owing to the deepening of these streams, is usually adequate, but in some shallow depressed areas the drainage is still imperfect. In small areas near the heads of streams the soil is overflowed but usually only at rare intervals. Further improvement in the drainage of the type could be readily effected.

Practically all of the Lamoure silt loam is under cultivation; only a few narrow strips along the stream channels, on which a few trees are grown, are used for pasture. Corn is the chief crop and yields range from 30 to 65 bushels per acre. Some oats are grown and alfalfa and sweet clover are produced. Truck gardening is practiced to a limited extent, chiefly along Soldier River.

The chief need of this soil to make it more productive is, first of all, adequate drainage, if this has not already been accomplished. The application of farm manure in small amounts is very desirable on this type. Large applications should not be made, and manure should not be supplied immediately preceding the growing of a small grain crop, owing to the danger of causing the crop to lodge. A phosphate fertilizer would undoubtedly prove valuable, and tests of superphosphate and rock phosphate are recommended.

### LAMOURE SILTY CLAY LOAM (111)

The Lamoure silty clay loam is one of the more important bottomland types and covers 2.6 percent of the total area. It occurs in several large areas in the Missouri River bottoms from Little Sioux southward to the Pottawattamie County line. There are a few areas along Soldier River from the Monona County line to its entrance into the Missouri River bottom, and a few small areas have also been mapped along Willow River and Boyer River. Along Boyer River there are many small areas which could not be shown on the map and they have been included with the areas of Wabash silt loam.

The Lamoure silty clay loam surface soil is a dark grayish-brown to black heavy plastic silty clay loam, extending to a depth of 10 inches. At this point it is underlaid by a dark brown or black plastic silty clay or clay loam to a depth of 24 inches. The subsoil is a light grayish-brown or yellowish-brown clay loam or clay. The lower subsoil is highly calcareous with many nodules and lime concretions present. Along the edges of the areas adjacent to the upland hill slopes, there is some colluvial silt laid down over the surface of the soil.

The type occurs on the outer edge of the bottoms nearest the upland slopes. In topography it is flat to depressed, and drainage is poor on much of the soil. Tiling is frequently necessary before satisfactory crop yields can be secured.

Where the soil is well drained and cultivated, general farm crops are successfully grown. Wild hay is produced on a few undrained areas. Corn is the chief crop, and yields of 35 to 70 bushels per acre are secured. Wheat yields 17 to 35 bushels per acre and oats 20 to 45 bushels. Clover and alfalfa yield 2½ to 4 tons of hay per acre. A few of the smaller areas along the tributary drainageways are utilized only for pasture purposes.

This soil is chiefly in need of adequate drainage to be more satisfactorily productive. It is also important that it be properly plowed and cultivated to prevent any clodding or baking. Fall plowing puts the soil into better physical condition for the preparation of the seed bed the succeeding spring. Small applications of farm manure also improve the physical condition of the soil. Large applications should not be made and especially not preceding the growing of a small grain crop as they may cause the crop to lodge. The addition of a phosphate fertilizer would undoubtedly be desirable on this soil, and tests of superphosphate and rock phosphate are recommended.

A few narrow strips of this type at the edge of former ponded areas are affected by a concentration of so-called alkali salts. These areas are quite unproductive until the excess salts have been removed. The treatments recommended for these spots are first of all adequate drainage which may be accomplished by laying a line of tile thru the middle of the spot, and then the incorporation of large amounts of organic matter, especially of fresh horse manure, with the soil. The turning under of a green crop of sweet clover or some other green manure material is also very desirable as an aid in reclaiming these so-called alkali soils. The application of a potash fertilizer to these spots has been found to be of value, and the use of muriate of potash at the rate of 50 to 100 pounds per acre may be very desirable. Tests are recommended, however, before the material is used extensively.

### LAMOURE SILTY CLAY (215)

The Lamoure silty clay is one of the more extensively developed bottomland types, covering 6.5 percent of the total area. It is found only on the bottomlands along the Missouri River. The largest area is adjacent to the bluffs along Allen Ditch in Taylor Township. It extends over an area more than 6 miles long by 2 miles wide. Other extensive areas are found in the vicinity of California, north and northwest of Little Sioux. Smaller areas are scattered over the Missouri bottoms.

The surface soil of the Lamoure silty clay consists of a heavy, plastic, black silty clay, underlaid at a depth of 16 or 18 inches by a grayish-brown or drab impervious clay. Mottlings of brown and reddish-brown occur in many parts of the subsoil. In some of the areas there are layers of silt 3 or 4 inches in thickness, below the surface soil. Sand is sometimes found in the areas beginning at a depth of 3½ feet from the surface soil. Where the sand is nearer the drab clay subsoil less gray and more brown mottling occurs. The subsoil is very high in lime, with an abundance of lime concretions present. Frequently lime extends up thru the surface soil. The area of the type near Little Sioux is flat and has a layer of sand under it at a depth of 3½ to 8 feet.

In topography the Lamoure silty clay is level to flat or depressed and the natural drainage of the type is very poor. Many of the areas near the bluffs are now inadequately drained. In a few places water will stand on the surface of the soil for long periods of time, making these areas unfit for cultivation. Drainage ditches are cut thru the larger bodies of the soil and these with the subsequent installation of tile permit of the drainage of the soil. The installation of Allen Ditch has taken care of much of the water which formerly ponded on this soil, flowing down from the uplands.

Nearly all of the soil is under cultivation. Corn is grown most extensively and yields range from 35 to 75 bushels per acre. Yields as high as 80 to 90 bushels have been reported on some well drained and cultivated areas. Wheat is grown in considerable acreages near California and yields range from 15 to 35 bushels per acre, depending on seasonal conditions. Alfalfa, sweet clover and oats are also grown to some extent. Oats tend to grow rank and lodge. Alfalfa yields average about 3 tons per acre.

The chief need of the Lamoure silty clay to make it more satisfactorily productive is adequate drainage. Where the soil is not thoroly drained, crop yields will not be satisfactory. The installation of tile may be necessary in connection with the ditching of the type to permit of adequate drainage. Great care should also be exercised in the plowing and cultivating of this type to prevent puddling and baking. Fall plowing is practiced to very good advantage and permits the soil to be kept in its best physical condition. The use of a phosphate fertilizer is very desirable on this soil, and tests of superphosphate and rock phosphate are recommended.

### WABASH SILT LOAM (26)

The Wabash silt loam is the most extensively developed bottomland type. Together with the colluvial phase, which is much smaller in extent, it covers 15 percent of the total area. It is the second largest type in the area. This soil is most extensively developed along Boyer River. Along this stream there are numerous large areas of the type covering the entire bottomland. The type is also found along all the creeks and their tributaries which extend thru the loessial sections of the county. There are only two areas of the type on the Missouri River bottoms and these are far from the river channel.

The surface soil of the Wabash silt loam is a dark brown friable silt loam, extending to a depth of 14 inches. At this point it grades into a faintly mottled brown clay loam or silty clay loam, underlaid at a depth of 24 inches by a black, tough, plastic, silty clay or clay. The soil is characteristically non-calcareous both in the surface soil and subsoil.

In the different areas of the type there are considerable variations in the texture of the surface soil. In small patches it will vary from a sand to clay, but the silt loam texture predominates. In the areas along the smaller tributary streams on the western side of the county, there is considerable light colored silt mixed with the darker soils, making the surface soil here lighter than typical. Along the smaller creeks and tributaries the subsoil is somewhat lighter textured, and the surface layer of silt loam is underlaid at a depth of 18 or 20 inches by a silty clay loam. Many areas and pockets where the subsoil is calcareous occur, especially along the larger creeks and Boyer River, and in the bottoms between Logan and Missouri Valley. Along Boyer River also there are patches of a light colored silt loam and a black silty clay loam too small to separate. Those have been included with the Wabash silt loam.

In topography the soil is nearly flat with a slight slope toward the river channels. Before the channels of Boyer River and of some of the larger creeks were straightened and deepened the flood waters frequently injured the crops seriously on this soil, but now only small narrow strips of bottomland along the smaller streams are subject to overflow. Here pastures are maintained. Tiling and ditching are not necessary on most of this land.

Most of the type is under cultivation. Only adjacent to the stream are there any native trees, and these areas are in pasture. Corn is the chief crop grown on the cultivated areas and yields 30 to 60 bushels per acre. Wheat and oats give fair yields but are apt to lodge in wet seasons. Alfalfa is grown very successfully and yields from 3 to $3\frac{1}{2}$ tons per acre. Truck crops are grown for home use and local markets.

To make this soil more productive, small amounts of farm manure are very desirable to stimulate the production of available plant food. Large applications should not be made preceding the growing of a small grain crop as there is danger of causing the crop to lodge. The use of a phosphate fertilizer is very desirable, and tests of superphosphate and rock phosphate are recommended.

### WABASH SILT LOAM (COLLUVIAL PHASE) (26a)

The colluvial phase of the Wabash silt loam is a rather extensively developed type, covering 6.4 percent of the total area. It occurs in all parts of the loessial area of the county, being found in many narrow strips along the drainage lines and intermittent drainageways of the smaller streams which extend into practically all parts of the loessial uplands. By far the greater portion of the intermittent drainage lines which flow thru the uplands, are made up of the colluvial phase of the Wabash silt loam.

The surface of this soil is a dark brown, friable silt loam, extending to a depth of 18 inches. It is underlaid by a slightly lighter colored and heavier textured silt loam or silty clay loam. The depth of the surface soil varies from 8 to 40 inches in different areas. The surface soil material is composed of a dark colored silt washed down from the hill slopes and deposited at the heads of and along the smaller drainage channels.

In topography this type is nearly flat. Drainage is good, however, owing to the open nature of the material. In a few of the small basin-like areas at the head of the tributary streams drainage is inadequate, and tiling is necessary.

All of this soil is under cultivation or in pasture, the larger portion being utilized for the growing of cultivated crops. Yields of corn are very much the same as those secured on the adjacent areas of the upland Marshall silt loam. Small grains are not grown very extensively as they are apt to lodge. Alfalfa grows very well and yields about the same as on the Marshall. This type should first be drained and then the addition of small amounts of farm manure to stimulate the production of available plant food is desirable. Manure should not be applied preceding the growing of the small grain crop as it may cause the crop to lodge. The use of a phosphate fertilizer is very desirable on this soil, and tests of superphosphate and rock phosphate are recommended.

### WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is an important type, covering 2.1 percent of the total area. It occurs in numerous areas, varying considerably in size, on the bottomlands. On the Missouri River bottoms this type is found only in Taylor and St. John Townships and in the northeastern corner of Cincinnati Township. The most extensive area occurs in St. John Township. Other small areas are found south of Yorkshire on Mosquito Creek, and a large depressed area occurs along Boyer River.

The surface soil of the Wabash silty clay loam is a dark brown or black silty clay loam, extending to a depth of 8 inches. It is underlaid by a dark brown, plastic, clay loam subsoil which at a depth of 24 inches is a very dark brown to black silty clay. In some places a layer of a lighter silty clay loam or silt loam from 4 to 6 inches in thickness occurs at depths varying from 8 to 24 inches. In poorly drained or swampy areas, the lower part of the subsoil is a drab or dull gray silty clay, mottled with dull gray and brown. The type is non-calcareous both in the surface and subsoil layers. Areas of the Lamoure silty clay loam too small to map separately are included with the areas of the Wabash silty clay loam.

In topography this soil is level to flat or depressed and the natural drainage is poor. Many of the areas are wet and swampy for long periods after prolonged rainfall. The straightening and deepening of the Boyer River and the installation of tile have made many areas more productive. Drainage is the first treatment needed for satisfactory crop yields on this soil.

In addition to drainage it is very important that the soil be properly handled to prevent puddling and baking. About 85 percent of the type is under cultivation, the remainder being mostly in pasture. Corn is the most important crop, and some wheat, alfalfa and oats are produced. Yields of these crops are much the same as on the Lamoure silty clay loam. Small amounts of farm manure would be of value on this soil to stimulate the production of available plant food. Large amounts should not be applied and especially not preceding the growing of a small grain crop, owing to the danger of causing the crop to lodge. The application of lime is necessary on this soil if legumes are to be grown. The addition of a phosphate fertilizer would undoubtedly be of value, and applications of superphosphate and rock phosphate are recommended for tests on individual farms.

### WABASH SILTY CLAY (27)

The Wabash silty clay is an important type, covering 3.2 percent of the total area. It occurs mainly on the Missouri River bottomlands in the western part of St. John Township, in the eastern part of Cincinnati Township and in the southern part of Taylor Township. One area is located in Boyer Township along Boyer River. Two small areas are found in Raglan Township.

The surface soil of the Wabash silty clay is a black plastic, impervious silty clay, extending to a depth of 18 inches. The subsoil is a black clay slightly lighter in color than the material above. In places the lower part of the subsoil is a dull gray or drab. In some areas there are thin layers of silt, clay or sand occurring at various places in the soil profile. Both the surface soil and subsoil are non-calcareous, thus differing from the Lamoure silty clay.

The type occurs in smaller ponded areas; the topography is flat to depressed, and natural drainage is poor owing to the heavy impervious nature of the surface soil and the subsoil. Large open ditches now carry the excess surface water and furnish outlets for lines of tile, which are necessary before this type can be properly cultivated. Practically none of the soil is at present subject to overflow.

The chief crops are corn and wheat. Corn yields 40 to 75 bushels and wheat 18 to 38 bushels per acre. Alfalfa grows very satisfactorily on well-drained areas and yields 2½ to 4 tons per acre. Poorly drained areas furnish good pasture, and 1 to 1½ tons of wild hay per acre are frequently cut from these lands.

This type is locally known as gumbo because of the waxy, impervious nature of the subsoil, the black tenacious surface soil and the poor drainage conditions. The chief treatment needed for the reclamation of these areas is first of all adequate drainage, which must be accomplished by the installation of tile in addition to the open ditches which have been installed. The proper cultivation of the soil is very important. Fall plowing is very desirable as it opens up the soil to the freezing and thawing action of the weather during the winter. This puts the seed bed in better condition for spring seeding. The incorporation of a small amount of farm manure is very desirable on this soil as it stimulates the production of available plant food. The use of lime is necessary if legumes are to be grown and the application of a phosphate fertilizer would undoubtedly be desirable. Tests of superphosphate and rock phosphate are strongly recommended.

### CASS SILT LOAM (106)

The Cass silt loam is an important type, covering 2.4 percent of the total area. It occurs in many areas on the Missouri River bottomlands, the largest area being about 3½ miles long and 1 mile wide, located north of Modale. Other areas of considerable size are found in St. John, Cincinnati, Clay and Morgan Townships. Small irregular bodies occur thruout the remainder of the Missouri River bottomlands.

The surface soil of the Cass silt loam is a dark brown, friable silt loam, extending to a depth of 8 inches. Below this point the soil is a dark brown very fine sandy loam in texture, extending to a depth of 30 inches. The subsoil below 30 inches is a yellowish-brown sand, highly calcareous. In places the upper layers of the subsoil are calcareous. Small patches of fine sand and sand occur in the silt loam areas, usually on slightly raised ridges or near old and new stream channels. Thin stratified layers of yellowish-brown or yellow sand occur in places in the surface soil. In the area 2½ miles east of Little Sioux the surface soil is slightly lighter colored than the typical.

In topography the Cass silt loam is mostly flat. Drainage is good owing to the open, porous nature of the subsoil. Practically none of the type is subject to overflow. The low areas near the river channels are leveed to prevent flooding.

The Cass silt loam is practically all under cultivation. A few areas are forested and used for pasture. Corn, alfalfa and wheat are the chief crops. Some oats, sweet potatoes, potatoes, onions and truck crops are also produced. Corn yields 30 to 60 bushels per acre; wheat 16 to 30 bushels and hay 2 to 3 tons.

This type will respond very profitably to applications of farm manure, and additions of manure are very desirable. The type may be slightly acid in the surface soil but it is usually well supplied with lime in the lower soil layers. The addition of a phosphate fertilizer would undoubtedly be worthwhile, and tests of superphosphate are strongly recommended.

### CASS SILTY CLAY LOAM (51)

The Cass silty clay loam is an important bottomland soil, covering 2.6 percent of the total area. It occurs in numerous areas on the Missouri River bottomland, many of which are quite extensive in size. The largest areas are found north of Mondamin and directly south and southeast of Mondamin. There are also extensive areas of the type thruout other sections of the bottomland along the Missouri River. Numerous small areas of the type are also mapped.

The surface soil of the Cass silty clay loam is a dark brown heavy plastic silty clay loam, extending to a depth of 14 inches. The subsoil at 14 inches is a brown or grayish-brown, friable silty clay loam. At 30 inches it is underlaid by a yellowish-brown sand or fine sandy loam. Below 20 inches the soil is calcareous and the subsoil effervesces when treated with hydrochloric acid. There is usually a gradual transition in texture from the silty clay loam to the lighter textured soil, and the boundaries between the Cass silt loam and the silty clay loam are rather arbitrarily placed.

In topography the Cass silty clay loam is level to flat, but the drainage is good because of the open, porous nature of the subsoil. The greater part of the soil, however, is subject to inundation at periods of floods. It is used for general farming purposes and nearly all is under cultivation. There are only a few scattered trees near the drainageways. The soil is largely used for corn, altho some wheat, alfalfa and oats are grown. Yields are slightly higher than on the Cass silt loam, except in wet seasons.

The need of this soil type to be made more productive is first of all for protection from overflow. When this is accomplished the soil will respond to small applications of farm manure to stimulate the production of available plant food. The addition of a phosphate fertilizer would undoubtedly be desirable, and tests of superphosphate are strongly recommended.

### CASS SILTY CLAY (216)

The Cass silty clay is a rather important type, covering 1.8 percent of the total area. It occurs in numerous areas, some of which are rather extensive in size, on the Missouri River bottomlands. The largest development of the type is in Little Sioux Township, north and west of Little Sioux, southwest of Modale and west and south of Mondamin. Numerous small areas of the type are scattered thru the bottomlands. The areas of the type range in size from 10 to 900 acres.

The surface soil of the Cass silty clay is a dark brown or black, tenacious silty clay, extending to a depth of 15 inches. At that point the subsoil becomes a tough clay, somewhat mottled with yellowish-brown and some iron stains. At 28 inches the material is a yellowish-brown silty very fine sandy loam, faintly mottled with brown and with iron stains. The subsoil of the type is highly calcareous, and frequently the surface soil is also calcareous.

In the northwestern corner of the county, along the Missouri River bottoms near the stream channel, there is a shallower phase of the soil which is subject to annual overflow. Here the surface soil is a dark brown plastic clay from 3 to 5 inches in depth. Below that point is a mottled brown material which varies in texture from a sandy clay loam to a clay. At a depth of 10 or 12 inches the underlying material is a light brown fine sand. In the area one and a quarter miles southwest of Modale, which is under water much of the time, the clay surface soil is black or dark brown to a depth of 1 to 3 inches, grading into a brown or light brown clay to a depth of 18 inches, where it rests on a yellowish-brown sand This area is swampy, low, depressed and naturally poorly drained.

In topography the Cass silty clay is level but rarely depressed except for the area southwest of Modale which lies from 4 to 6 feet below the adjacent bottomland. The surface soil and upper subsurface are poorly drained, owing to the impervious nature of the soil material, but the lower part of the subsoil provides good underdrainage.

Except for the area in the northwestern corner of the county where the only growth is coarse grasses and scattered willow clumps, and the area one and a quarter miles southwest of Modale, where there is a thin forest growth, the soil is mostly under cultivation. The few lightly timbered areas are used for pasture. Corn, wheat and alfalfa are the chief crops grown on the cultivated areas. Yields are very similar to those secured on the Cass silty clay loam.

This type's chief need is protection from overflow, for satisfactory crop yields. A small amount of farm manure would be of value on the soil to stimulate the production of available plant food. Large applications would not be desirable. The use of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended.

## CASS VERY FINE SANDY LOAM (217)

The Cass very fine sandy loam is a minor type, covering only 0.4 percent of the total area. It occurs in small areas in only three townships, Little Sioux, Morgan and Clay. The 2 largest areas are located two and four and one-fourth miles northwest of Modale. Three small areas occur northwest of Mondamin, one south of River Sioux and one adjoining River Sioux on the west.

The surface soil of the Cass very fine sandy loam is a dark brown very fine sandy loam, extending to a depth of 9 inches. At this point there is a brown or dark brown very fine sandy loam which becomes gradually lighter in texture at the lower depths and in the deeper parts of the subsoil in many places there is a brown very fine sand. The entire soil section is highly calcareous.

In topography the Cass very fine sandy loam is flat to gently undulating. The open texture of the soil allows good drainage which becomes excessive in some seasons and crops are frequently injured by drouth. The type is not subject to overflow.

The soil is farmed largely with the other soils and is cropped to corn, oats, potatoes and wheat. The yields are very similar to those secured on the Cass silt loam except in seasons of poor rainfall. For higher productivity, the type is particularly in need of organic matter, and liberal applications of farm manure would be very desirable. The turning under of leguminous crops for green manuring purposes would also be of material help. The use of a phosphate fertilizer would undoubtedly prove worthwhile, and tests of superphosphate are recommended.

## SARPY SILT LOAM (89)

The Sarpy silt loam is an important type. Together with the deep phase which is somewhat smaller in area, it covers 1.6 percent of the total area. The type is developed mainly near the Missouri River channel and near the Little Sioux and Soldier Rivers from one to three miles back from their entrance into the Missouri River. The areas are scattered, irregular and mostly rather limited in size. The largest development of the type is southwest of Little Sioux.

The surface soil of the Sarpy silt loam is a light brown or brown friable silt loam, containing considerable amounts of very fine sand and extending to a depth of 12 inches. The subsurface layer varies in color from a light brown to a brown and ranges in texture from a heavy silt loam to a sandy silty clay loam. At a depth of 28 inches the subsoil is a lighter brown or grayish-brown very fine sand. Below 30 inches there are a few iron stains. The surface soils are highly calcareous and the calcareous material extends thruout the soil section.

In many places near the surface of the soil there are thin layers, 2 to 3 inches thick, of a material varying in texture from a fine sand to a silty clay loam. Many variations occur in the texture of the surface soil. There are small patches of clay, very fine sand, and of mixtures of alluvial material. Two and a half miles west of Modale a large area occurs in which the surface soil is a grayish-brown to yellowish-brown and other areas where this variation from the typical soil occur, are found in the large horseshoe bend of the Missouri River three and a half miles west of California near Blair Ferry. A small depressed area of the Cass silty clay loam, too small to show on the map, occurs in the town of Little Sioux.

In topography the Sarpy silt loam is level to flat and in one area which occurs one-fourth of a mile southeast of Blair Ferry it is depressed. There are occasional hummocks and ridges in the soil, usually near old stream channels. Drainage is adequate because of the open porous nature of the soil. Only a few of the areas of the type are subject to overflow.

Practically all of the Sarpy silt loam is under cultivation. Corn, alfalfa, oats, potatoes and some truck crops are grown. Corn yields 25 to 50 bushels per acre; alfalfa 2½ to 3½ tons; other crops give good yields.

The needs of this soil to make it more productive are for organic matter, primarily. Liberal applications of farm manure would be of large value and the turning under of leguminous crops as green manures would also aid crop yields materially. The use of a phosphate fertilizer would undoubtedly be desirable and tests of superphosphate are strongly recommended. For potatoes and truck crops, the use of a complete commercial fertilizer might be of considerable value and tests of good brands of commercial fertilizers would be desirable for these crops.

### SARPY SILT LOAM (DEEP PHASE) (218)

This phase of the Sarpy silt loam is limited in extent, occurring in irregular, widely scattered areas mostly in the Missouri River Valley bottomlands. Two small areas occur, however, along Soldier River, one and a half miles north of Orton and one-half mile north of Pisgah. There is also a small area in Section 33 of Boyer Township along Boyer River. The areas developed in the Missouri River bottomlands are small and irregular in size, the largest individual area being found west of Mondamin.

The surface soil of the deep phase of the Sarpy silt loam is a friable, light brown silt loam, extending to a depth of 12 inches. Below that point the soil is a light brown clay loam to a depth of 28 inches, from there changing to a darker olive brown tenacious clay. The subsoil is highly calcareous, and calcareous material usually occurs thruout the entire soil section.

In places there are layers of a yellow calcareous sand, occurring at a depth of about 24 inches. Much fine sand and very fine sand is mixed in with the soil in many areas, particularly in the Missouri River bottoms where the subsoil is slightly heavier. In the area north of Pisgah, the soil is somewhat mixed, the subsoil in places being almost as light in texture as the surface soil and there is some wash from the upland over the type.

In topography this phase of the Sarpy silt loam is flat and in the areas lying nearest the Missouri River channel there are occasional ridges and hummocks where old dry drainage channels occur. There are a few depressed areas of the type where drainage is poor, but on most of the areas drainage is good. Only in the areas along the smaller stream channels, which have not been deepened or straightened, is there serious injury from overflow.

The soil is all under cultivation or in pasture. Small clumps of trees grow along the narrow bottoms near the present or old stream channels. On the cultivated areas corn is the chief crop, altho some alfalfa, sweet clover, oats, wheat, truck crops, melons and potatoes are produced. Corn yields from 25 to 50 bushels per acre and hay from $1\frac{1}{2}$ to 3 tons. The soil is particularly in need of organic matter to be made more productive, and liberal applications of farm manure are recommended. The turning under of leguminous crops as green manures would also be of value. The application of a phosphate fertilizer would undoubtedly help, and tests of superphosphate are strongly urged. Where truck crops are grown, the use of a good complete commercial fertilizer might be of value.

### SARPY SILTY CLAY LOAM (DEEP PHASE) (219)

The Sarpy silty clay loam, deep phase, is a minor type, covering only 0.1 percent of the total area. It is practically all found in Cincinnati Township in the Missouri River bottomlands, and the areas are small and irregular and located about two and one-fourth miles northwest of California.

The surface soil of the deep phase of the Sarpy silty clay loam is a heavy plastic brown silty clay loam, extending to a depth of 8 inches. Below that point the subsoil is a heavy tenacious silty clay to clay, highly mottled with yellowish-brown and containing rusty brown iron concretions and stains. The surface soil is usually calcareous and the calcareous material extends thruout the entire soil section. In topography this type is flat to depressed and natural drainage is poor.

Most of this soil is under cultivation and general farm crops are grown. The yields are very much the same as on the Lamoure silty clay loam, and the needs of the type are also similar. Small amounts of farm manure would undoubtedly be of value in stimulating the production of available plant food. There is not the danger of causing crops to lodge on this type from the use of farm manure as is the case with the Lamoure silty clay loam and the Wabash silty clay loam. The turning under of leguminous crops for green manure purposes would also be of value. The application of a phosphate fertilizer would undoubtedly prove worthwhile, and tests of superphosphate are strongly recommended. The first treatment needed before this soil is brought under cultivation is adequate drainage. Until this is accomplished there is very little assurance of satisfactory crop yields.

### SARPY SILTY CLAY (220)

The Sarpy silty clay is a rather important type in the bottomland, covering 1.1 percent of the total area of the county. It occurs in numerous areas on the Missouri River bottomlands adjacent to the stream channels. The largest developments of the type are found directly west of Modale and along the river to the north and west of Little Sioux.

The surface soil of the Sarpy silty clay is a brown tenacious silty clay, extending to a depth of 6 inches. At this point there is a shallow subsurface layer from 5 to 10 inches in thickness, consisting of a light brown or grayish-brown silty clay loam. The subsoil is a yellowish-brown medium sand, mottled in places with iron stains. The subsoil is highly calcareous, and the calcareous material usually extends thruout the soil section.

The depth of the surface soil and the subsurface layer varies. In some areas the soil is 10 to 12 inches in thickness and the subsurface layer in many places is a light brown plastic clay loam, extending to a depth of 20 inches. In some of the deeper depressions the heavier subsurface layer over the sand may be 30 inches in depth. In the areas in Sections 10 and 21 of Clay Township and Section 8 of Cincinnati Township, the surface soil is heavier in texture, varying in depth from 10 to 30 inches overlying sand, and is uniformly light in color.

In topography the Sarpy silty clay is low to depressed and, except for the areas in Sections 10 and 21 of Clay Township and Section 8 of Cincinnati Township, is subject at times to overflow. The areas along the lower bottoms are separated from the river channel by riverwash, and the narrow swales filled in with clay and silt, low hummocks, and narrow ridges of sand are all of recent origin. The area two miles west of Modale in Sections 26 and 35 of Clay Township occurs in an old river channel or shallow lake bed and supports only a luxuriant growth of slough grass. Tall cottonwood trees, dense willow clumps and thickets cover much of the area in this type, and there is a scant growth of coarse grasses. The old channel and lake swales are soggy and wet in places.

Very little of this type is cultivated, and in some areas the drainage is quite restricted. The tillable land is used for corn, alfalfa and wheat, but the yields are somewhat lower than on the Cass silty clay. Small applications of farm manure would stimulate the production of available plant food and improve the physical condition of the soil in these cultivated areas. A phosphate fertilizer would also undoubtedly be desirable, and tests of superphosphate are recommended. Leguminous crops used as green manures would also be of value in building up the organic matter content of the soil.

### SARPY VERY FINE SANDY LOAM (28)

This is a minor type, covering only 0.6 percent of the total area. It occurs in numerous small areas in the Missouri River bottoms, the largest development of the type being found in the southwestern corner of the county, separated from the river channel by the Sarpy silty clay loam and the Sarpy fine sand. The largest area of the type is one mile southeast of Blair Ferry.

The surface soil of the Sarpy very fine sandy loam is a light brown or grayish-brown very fine sandy loam, extending to a depth of 14 inches. The subsoil is a grayish-brown, fine sandy loam somewhat lighter in texture than the surface soil. In places pockets and layers of coarse sand and gravel occur. The subsoil is highly calcareous, and the calcareous material usually extends thruout the soil section.

Small areas of very fine sand and fine sand occur in ridges, mounds and hummocks, which cannot be indicated on the map but are included with the type. Two miles west of Mondamin is a rather large, high, flat area in which the texture of the surface soil varies from a silt loam to a very fine sand. In topography the Sarpy very fine sandy loam is flat to gently undulating with ridges along or near the old channels on the lower bottoms. In the area one mile southeast of Blair Ferry, the southern part is spotted with large mounds from 40 to 60 feet across and from 2 to 6 feet in height. The soil is well drained and even excessively drained, and in periods of prolonged dry weather crops suffer. Only a small portion of the area is subject to overflow.

About 70 percent of the total area of the type is cropped, corn being the chief crop. On the cultivated sections there is a thin, scattered growth of trees and some pasture is provided. On the cultivated section, in addition to corn, alfalfa is grown; and some potatoes, melons and onions are produced. Corn yields from 15 to 40 bushels per acre in favorable seasons.

This type is chiefly in need of additions of organic matter to be made more productive in the cultivated areas. The liberal application of farm manure is very desirable, and the turning under of leguminous crops as green manures would also be of large value. The use of a phosphate fertilizer would undoubtedly increase crop yields to a considerable extent, and tests of superphosphate are strongly recommended. When truck crops are grown the use of a good complete commercial fertilizer might be of value.

## SARPY FINE SAND (133)

The Sarpy fine sand is a minor type, covering 0.2 percent of the total area. It is found mainly in two townships, Clay and Cincinnati. Areas occur two and one-half miles west of Modale and one-half mile east of Blair Ferry. There is a low area in the horseshoe bend of the Missouri River northwest of River Sioux and two small areas are found two miles south of Blair Ferry. Other small areas of the type occur thruout the Missouri River bottomland.

The surface soil of the Sarpy fine sand consists of a mixture of sandy material, varying in texture from a very fine sand to a medium sand and ranging in color from a light yellowish-brown to a grayish-brown. At a depth of 10 inches the material becomes a light yellowish-brown fine sand and there is little change in texture thruout the soil section, the lower part of the subsoil containing only slightly more coarse sand than the surface layers. Where a heavy grass growth covers the soil, the surface layer is slightly darker to a depth of 4 to 6 inches. The surface soil is calcareous, and the subsoil is everywhere highly calcareous.

In the areas in the horseshoe bend of the Missouri River northwest of River Sioux and in the two areas two miles south of Blair Ferry, the soil is subject to overflow. The other developments of the type are above ordinary overflow. The area three and a half miles northwest of River Sioux is nearly all waste land. It contains billowy surface ridges, irregular sand mounds 2 to 10 feet in height, small depressed areas covered thinly with clay or very fine sandy loam, and ponded areas from 25 to 50 feet across that are filled with a coarse growth of weeds. There is a sparse growth of trees and willow clumps there and also on this same type of land near the main channel of the river in both Cincinnati and Clay Townships. Near Blair Ferry is an area of this soil in which irregular hummocks and sand ridges of fine and medium sand extend to a height of 5 to 8 feet.

Only a small part of this soil is cropped. Corn, melons and truck crops, and a little alfalfa and rye, are grown. The type is inclined to be drouthy and is in need of organic matter to build up its supply and to make it less subject to injury in dry seasons. Liberal applications of farm manure are very desirable, and the turning under of leguminous crops as green manures would also help materially. The addition of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are strongly recommended. For melons and truck crops, which may be grown successfully on this soil, the use of a good complete commercial fertilizer would undoubtedly be of value.

### RAY SILT LOAM (195)

This is a minor type, covering only 0.1 percent of the total area. It occurs in narrow strips along rivers or small tributary streams. Small areas are found along Boyer River, four miles northeast of Missouri Valley, between Calhoun and Missouri Valley, along Willow River, in Section 11 of Taylor Township, and two and one-half miles northeast of Mondamin along the artificial drainage ditch.

The surface soil of the Ray silt loam consists of a light brown to brown silt loam, extending to a depth of 6 inches. At that point there is a subsurface layer of a black tenacious silty clay. The subsoil is a heavy silt loam to silty clay loam. In places the surface soil varies in texture from a heavy silt loam to a light silty clay loam. The soil consists of material which has been washed down from the light colored bluffs and hill slopes and spread out over the black alluvial clay soils along the Missouri River bottomlands near the bluff line.

The type is mostly under cultivation, and general farm crops are grown. The crop yields are similar to those obtained on the Sarpy silt loam. The chief need of the soil is for drainage, if it is to be made satisfactorily productive. The use of farm manure would undoubtedly be of value, and small applications would stimulate the production of available plant food. The addition of a phosphate fertilizer would undoubtedly help, and tests of superphosphate are recommended.

### RIVERWASH (53)

Riverwash covers 1.0 percent of the total area. Large areas of this material occur southwest and northwest of California along the river channel, and another rather extensive area is found along the river channel northwest of Mondamin. Others are found along the Missouri River in various places, a rather extensive development occurring in the northwestern corner of the county.

Riverwash includes waste land along the channel of the Missouri River and consists mainly of sandbars and coarse sandy alluvial material flooded by the river at flood waters. The recently deposited material is a mixture of sand, silt and clay. Flats of grayish-brown silty clay underlaid by sand at depths from 4 to 16 inches occur in many places between old channels of the river. There is a constant shifting in the channel of the river, and much of the land is found along older cut-offs which were probably a part of the main channel at one time. The areas of the soil lie from 2 to 8 feet above the normal water level of the river and are flooded frequently during the year. Uneven layers or deposits of sand, silt and clay are left after each flooding. The sandy deposits are shifted by strong winds, and the topographic features include large ridges and dunes from 2 to 6 feet high.

None of the area of riverwash is cultivated, and a dense growth of willows covers much of it. On the higher flats cultivation might be possible but because of frequent overflow and the fact that the areas are cut by old channels and sloughs, it would be rather difficult to secure satisfactory yields of any cultivated crops. The area of this soil may be considered practically all waste land.

# 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 co-operation with the Bureau of Soils of the United States Department of Agriculture.

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

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

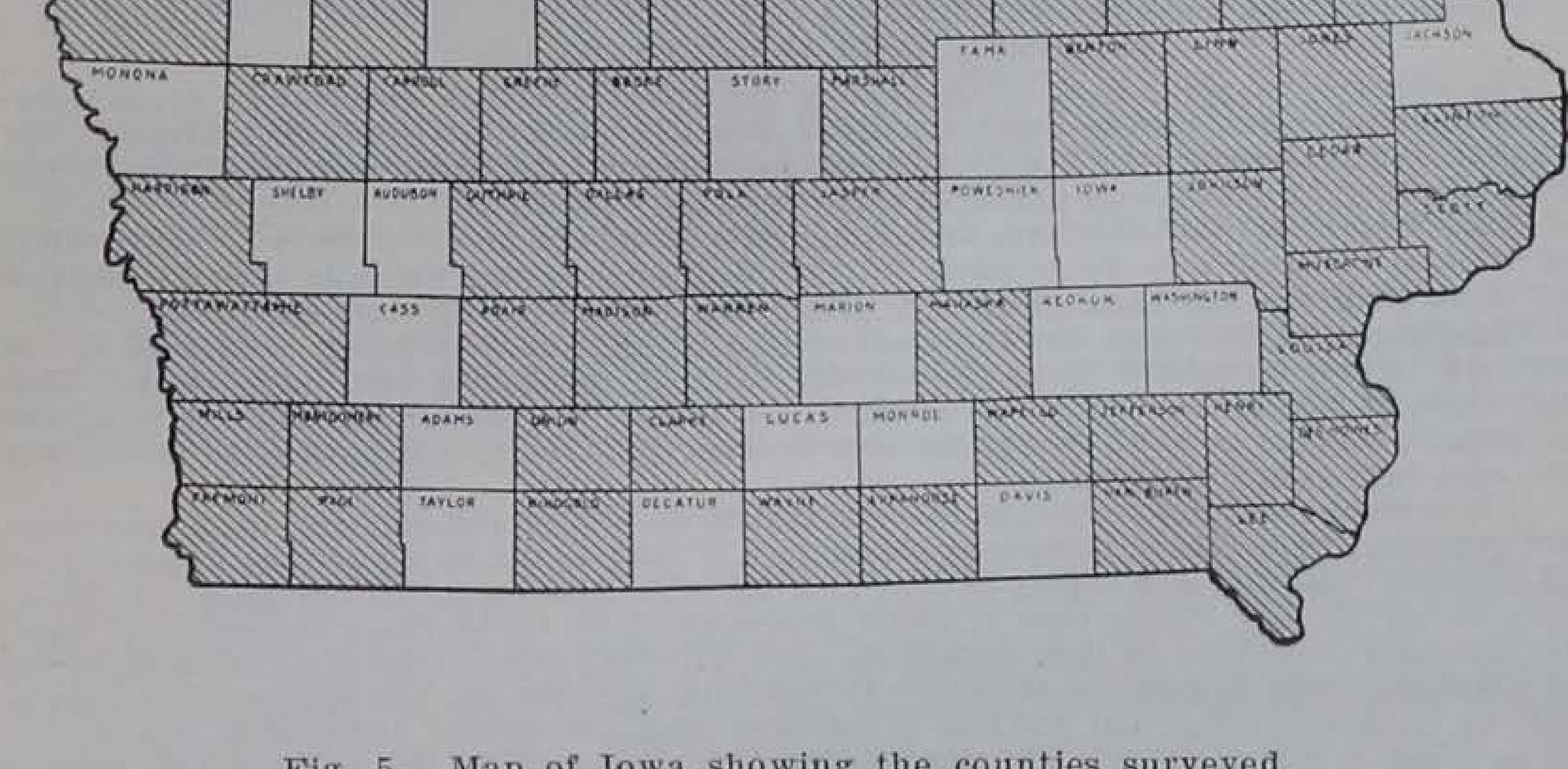



Fig. 5. Map of Iowa showing the counties surveyed.

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

## *PLANT FOOD IN SOILS*

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

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

### THE "SOIL DERIVED" ELEMENTS

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

### AVAILABLE AND UNAVAILABLE PLANT FOOD

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

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

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

### REMOVAL OF PLANT FOOD BY CROPS

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

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

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

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

TABLE I. PLANT FOOD IN CROPS AND VALUE

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

| Crop | Yield | Plant Food, Lbs. | | | Value of Plant Food | | | Total Value of Plant Food |
|---|---|---|---|---|---|---|---|---|
| | | Nitrogen | Phosphorus | Potassium | Nitrogen | Phosphorus | Potassium | |
| Corn, grain | 75 bu. | 75 | 12.75 | 14 | $12.00 | $1.52 | $0.84 | $14.37 |
| Corn, stover | 2.25 T. | 36 | 4.5 | 39 | 5.76 | 0.54 | 2.34 | 8.64 |
| Corn, crop | ------- | 111 | 17.25 | 53 | 17.76 | 2.07 | 3.18 | 23.01 |
| Wheat, grain | 30 bu. | 42.6 | 7.2 | 7.8 | 6.81 | 0.86 | 0.46 | 8.13 |
| Wheat, straw | 1.5 T. | 15 | 2.4 | 27 | 2.40 | 0.28 | 1.62 | 4.30 |
| Wheat, crop | ------- | 57.6 | 9.6 | 34.8 | 9.21 | 1.14 | 2.08 | 12.43 |
| Oats, grain | 50 bu. | 33 | 5.5 | 8 | 5.28 | 0.66 | 0.48 | 6.42 |
| 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 |

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 losses.

### REMOVAL FROM IOWA SOILS

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

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

## *PERMANENT FERTILITY IN IOWA SOILS*

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

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

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

## CULTIVATION AND DRAINAGE

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

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

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

## THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops 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 are a number of explanations of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In proper rotations the time between two different crops of the same plant is long enough to allow the "toxic" substances to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

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

## MANURING

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

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

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

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

## THE USE OF PHOSPHORUS

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

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

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

## LIMING

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

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown.

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.

## *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 areas. The various areas are shown in the map, fig. 10.

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

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

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

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

## THE SOIL SURVEY BY COUNTIES

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

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

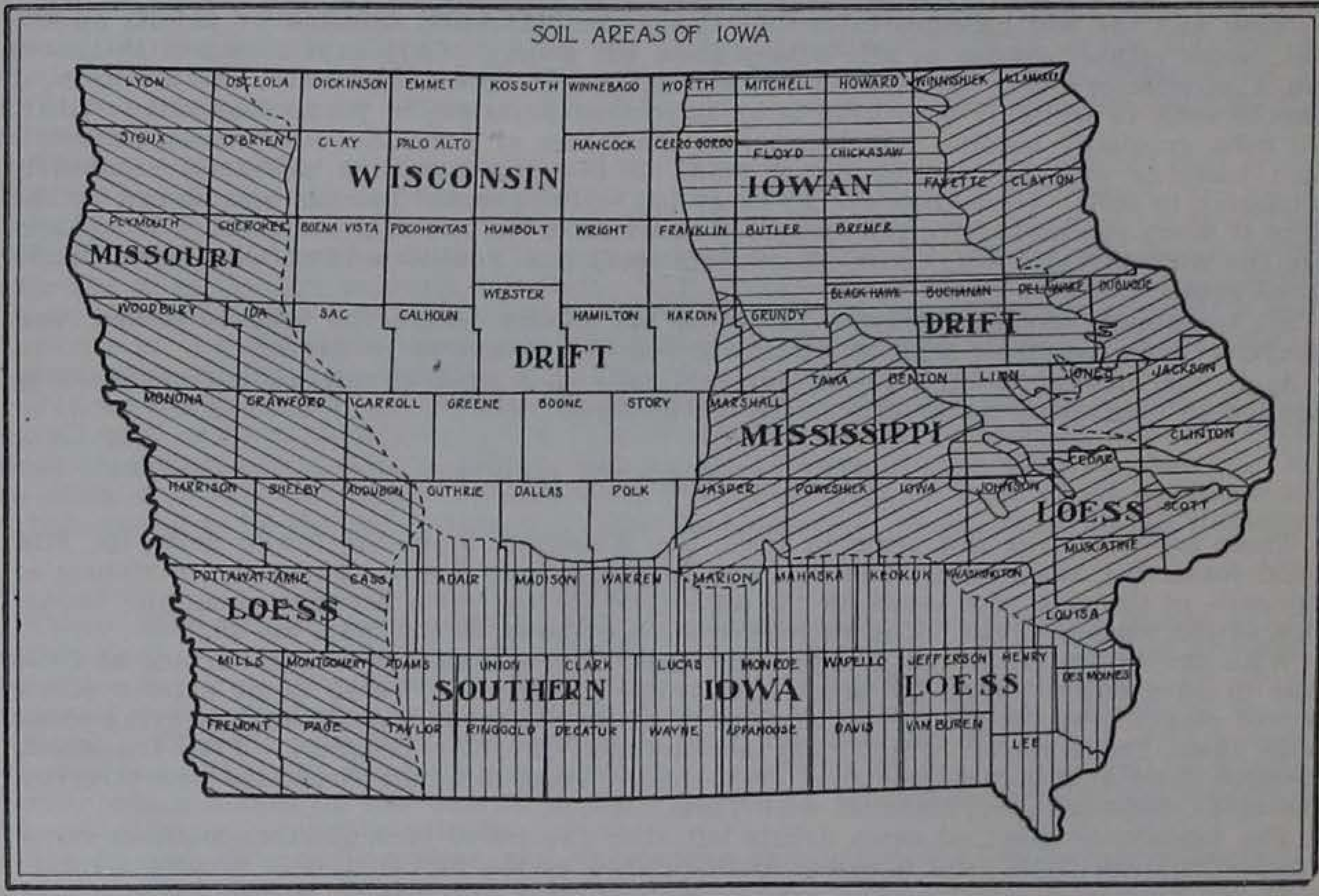



Fig. 6. Map showing the principal soil areas in Iowa.

## GENERAL SOIL CHARACTERISTICS

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

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

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

The common soil constituents may be given as follows:†

| | |
|---|---|
| Organic matter | All partially destroyed or decomposed vegetable and animal material. |
| Inorganic matter | Stones—over 32 mm.*<br>Gravel—32—2.0 mm.<br>Very coarse sand—2.0—1.0 mm.<br>Coarse sand—1.0—0.5 mm.<br>Medium sand—0.5—0.25 mm.<br>Fine sand—0.25—0.10 mm.<br>Very fine sand—0.10—0.05 mm.<br>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 per cent or more of organic matter, sometimes mixed with more or less sand or soil.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

*Gravels*—More than 50 per cent 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 determinations of soil types are verified also by inspection and by consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps of field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

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

# IOWA AGRICULTURAL EXPERIMENT STATION

PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA

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

## BULLETINS

No.
78 Drainage Conditions in Iowa.*
82 The Principal Soil Areas of Iowa.*
95 The Maintenance of Fertility with Special Reference to the Missouri Loess.*
98 Clover Growing on the Loess and Till Soils of Southern Iowa.*
119 The Gumbo Soils of Iowa.*
124 A Centrifugal Method for the Determination of Humus.*
150 The Fertility in Iowa Soils.*
150 The Fertility in Iowa Soils (Popular Edition).
151 Soil Acidity and the Liming of Iowa Soils.*
151 Soil Acidity and the Liming of Iowa Soils (Abridged).*
157 Improving Iowa's Peat and Alkali Soils.*
161 Maintaining Fertility in the Wisconsin Drift Soil Areas of Iowa.*
167 Rotation and Manure Experiments on the Wisconsin Drift Soil Areas.
177 The Alkali Soils of Iowa.
183 Soil Erosion in Iowa.*
191 Reclaiming Iowa's Push Soils.
213 Iowa System of Soil Management.*
221 Crop Yields on Soil Experiment Fields in Iowa.
232 Field Experiments with Gypsum.
236 The Economic Value of Farm Manure as a Fertilizer on Iowa Soils.
241 Crop Returns Under Various Rotations in the Wisconsin Drift Soil Area.

## CIRCULARS

2 Liming Iowa Soils.*
7 Bacteria and Soil Fertility.*
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9 Farm Manures.*
10 Green Manuring and Soil Fertility.*
15 Testing Soils in Laboratory and Field.*
24 Fertilizing Lawn and Garden Soils.
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## RESEARCH BULLETINS

1 The Chemical Nature of the Organic Nitrogen in the Soil.*
2 Some Bacteriological Effects of Liming.*
3 Influences of Various Factors on the Decomposition of Soil Organic Matter.*
4 Bacterial Activities in Frozen Soils.*
5 Bacteriological Studies of Field Soils, I.*
6 Bacteriological Studies of Field Soils, II.*
8 Bacteria at Different Depths in Some Typical Iowa Soils.*
9 Amino Acid and Acid Amides as Source of Ammonia in Soils.*
11 Methods for the Bacteriological Examination of Soils.*
13 Bacteriological Studies of Field Soils, III.*
17 The Determination of Ammonia in Soils.
18 Sulfofication of Soils.
24 Determination of Amino Acids and Nitrates in Soils.
25 Bacterial Activities and Crop Production.
34 Studies of Sulfification.
35 Effects of Some Manganese Salts on Ammonification and Nitrification.
36 Influence of Some Common Humus-Forming Materials of Narrow and Wide Nitrogen-Cargon Ratio on Bacterial Activities.
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45 Soil Inoculation with Azotobacter.
56 The Effect of Seasonal Conditions and Soil Treatment on Bacteria and Molds in the Soil.
58 Nitrification in Acid Soils.
76 The Relationships between Hydrogen Ion, Hydroxyl Ion and Salt Concentrations and the Growth of Seven Soil Molds.
87 A Study of the Secondary Effects of Hill Fertilization.
104 Some Effects on Methods of Applications of Fertilizers on Corn and Soils.*
109 The Numbers of Microorganisms in Carrington Loam as Influenced by Different Soil Treatments.
110 Studies on Nitrification and Its Relation to Crop Production on Carrington Loam Under Different Treatments.
113 Physiological Studies on the Nitrogen Fixing Bacteria of the Genus Rhizobium.
114 Soybean Inoculation Studies.