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# SOIL SURVEY OF IOWA WRIGHT COUNTY

AGRICULTURAL EXPERIMENT STATION  
IOWA STATE COLLEGE OF AGRICULTURE  
AND MECHANIC ARTS

Agronomy Section  
Soils



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Soil Survey Report No. 31

June, 1923

Ames, Iowa

# IOWA AGRICULTURAL EXPERIMENT

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- 1 The Chemical Nature of the Organic Nitrogen in the Soil.\*
- 2 Some Bacteriological Effects of Liming.\*
- 3 Soil Inoculation.
- 4
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- 6 Bacteriological Studies of Field Soils, II.\*
- 8 Bacteria at Different Depths in Some Typical Iowa Soils.\*
- 9 Amino Acid and Acid Amides as Sources of Ammonia 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 in Sulfofication.
- 35 Effects of Some Manganese Salts on Ammonification and Nitrification.
- 36 Influence of Some Common Humus-Forming Materials of Narrow and of Wide Nitrogen-Carbon Ratio on Bacterial Activities.
- 39 Carbon Dioxide Production in Soils and Carbon and Nitrogen Changes in Soils Variously Treated.
- 43 The Effect of Sulfur and Manure on the Availability of Rock Phosphate in Soil.
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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.

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| 1 Bremer County.        | 12 Clay County.        | 23 Winnebago County. |
| 2 Pottawattamie County. | 13 Montgomery County.  | 24 Polk County.      |
| 3 Muscatine County.     | 14 Black Hawk County.  | 25 Marshall County.  |
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June, 1923

Soil Survey Report No. 31

# SOIL SURVEY OF IOWA

## Report No. 31—WRIGHT COUNTY SOILS

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

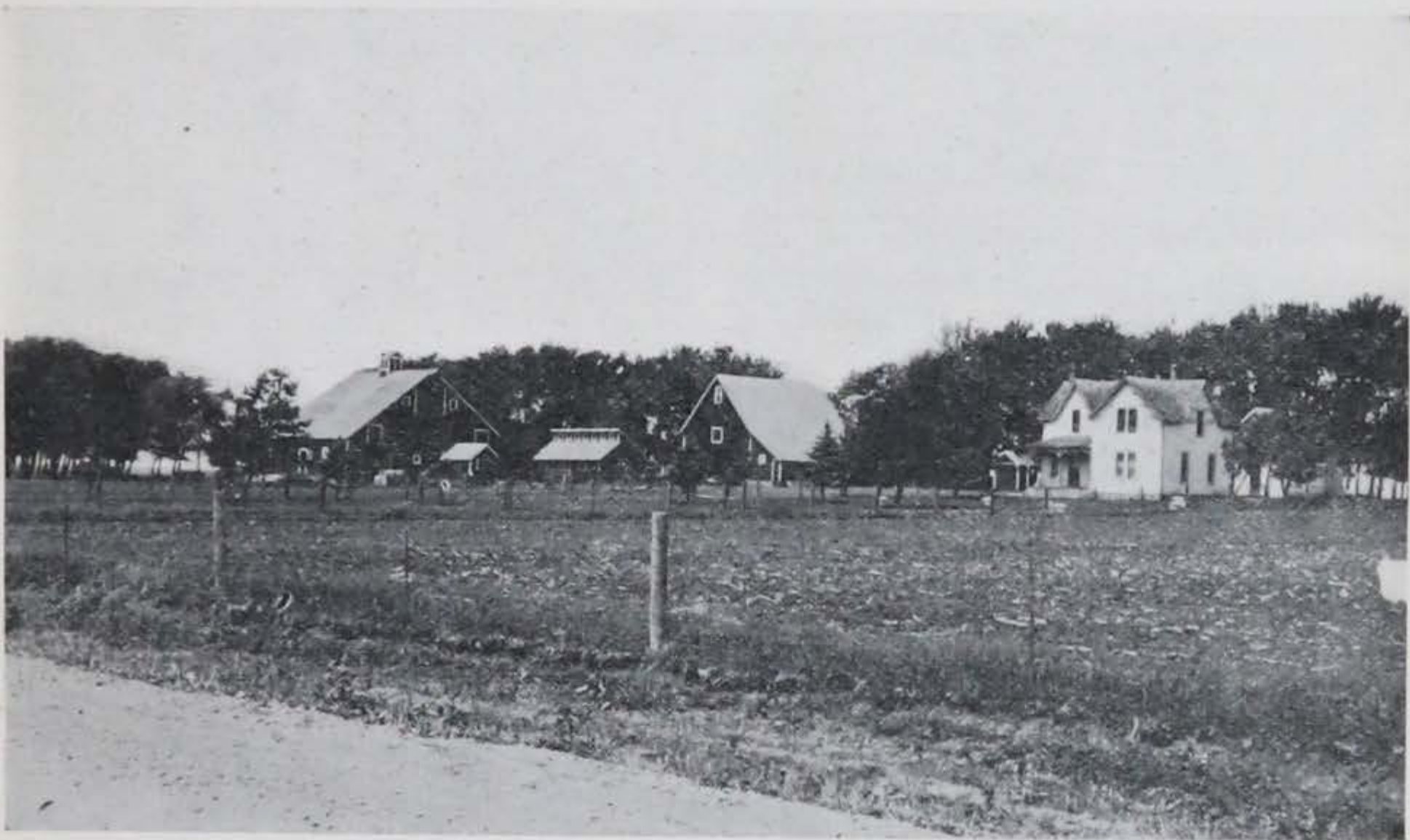


Fig. 1. A typical farmstead in Wright county.

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# WRIGHT COUNTY SOILS\*

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

**W**RIGHT COUNTY is located in north central Iowa, in the third tier of counties south of the Minnesota state line. It lies in the Wisconsin drift soil area and its soils are all of drift origin.

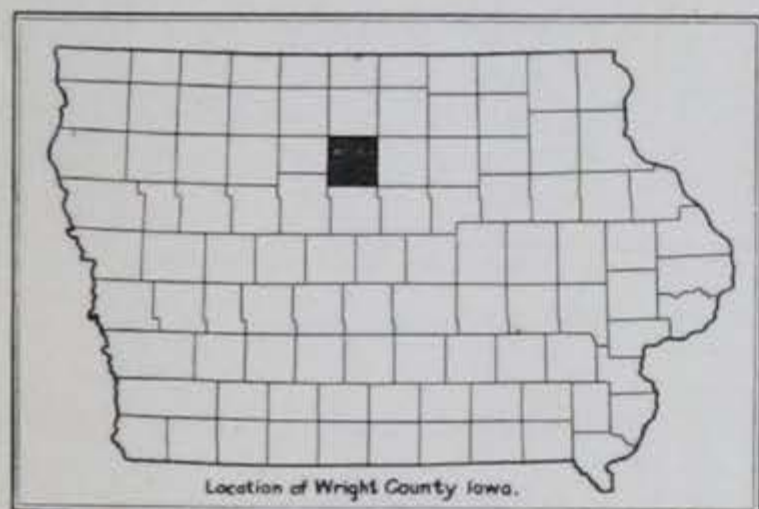


Fig. 2. A map showing the location of Wright county.

The total area of Wright county is 575 square miles or 368,000 acres. Of this area 345,826 acres, of 93.9 percent, is in farm land. The total number of farms is 1,832 and the average size of the farms is 189 acres. In 1920 52 percent of the farms in this county were operated by tenants.

The following figures taken from the Iowa Yearbook of Agriculture for 1921 show the utilization of the farm land of the county:

Acreage in general farm crops.....	249,460
Acreage in pasture.....	66,036
Acreage in farm buildings, feed lots and public highways.....	17,260
Acreage in waste land.....	3,709
Acreage in crops not otherwise listed.....	1,429

## THE TYPE OF AGRICULTURE IN WRIGHT COUNTY

The prevailing type of agriculture in Wright county is a general farming system, including grain growing and the raising and feeding of hogs, cattle and other livestock. Much corn and oats was sold out of the county in previous years but now larger portions of the crops grown are used for feed on the farms and the livestock industry is becoming more important. Hog raising is the most important livestock industry and hog feeding is practiced extensively. The beef cattle industry is second in importance, many cattle being raised on the farms and considerable numbers shipped in for feeding. Sheep raising and horse raising are practiced to some extent. Dairying is of minor importance. Poultry raising is providing considerable income on many farms.

The acreage in waste land in the county is considerable and much of this land might be reclaimed thru proper treatment. The causes of infertility are variable and hence general recommendations cannot be given for the reclamation of unproductive areas. Drainage is often the treatment needed first and many areas may be made highly productive by the installation of tile. Other treatments are needed in many cases, however, and in a later section of this report suggestions will be offered regarding the best methods of handling individual soils. In special cases for more or less abnormal soil conditions, advice will be furnished by the Soils Section of the Iowa Agricultural Experiment Station upon request.

\*See Soil Survey of Wright County, Iowa, by T. H. Benton of the Iowa Agricultural Experiment Station and C. O. Jaeckel of the U. S. Dept. of Agriculture.

TABLE I. ACREAGE, YIELDS AND VALUE OF CROPS GROWN IN WRIGHT COUNTY, IOWA\*

Crops	Acres	Percentage of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn .....	120,000	34.69	39.0	4,680,000	\$0.30	\$1,404,000
Oats .....	95,000	27.47	25.0	2,375,000	0.23	546,250
Winter wheat .....	40	0.01	12.0	480	0.90	432
Spring wheat .....	240	0.06	13.0	3,120	0.87	2,714
Barley .....	890	0.25	28.0	24,920	0.42	10,466
Rye .....	50	0.01	17.0	850	0.73	620
Potatoes .....	920	0.26	34.0	31,280	1.40	43,792
Tame hay .....	26,500	7.66	1.4	37,100	9.08	336,868
Wild hay .....	5,700	1.64	1.0	5,700	7.47	42,579
Alfalfa .....	120	0.03	3.66	439	12.92	5,668
Pasture .....	66,036	19.09	.....	.....	.....	.....

The acreage, yield and value of the crops grown in Wright county are shown in table I.

Corn is the most important crop, occupying about 35 percent of the total farm land. In 1921, average yields of 39 bushels per acre were reported. Much higher yields than this are secured in individual cases. On the black heavy prairie soils, when they are well drained, the yields are much higher than on the lighter, more rolling types. Reid's Yellow Dent is the variety most commonly grown. Other varieties in use are Silver King, Little Iowa, Silver Mine, Minnesota 13 and Murdock's Yellow Dent. A small part of the corn crop is used for silage. Most of it is used for feed for hogs, cattle and work stock. On many farms, however, a large part is sold to local elevators and only a comparatively small part is fed. The practice of feeding is increasing at the present time. A small part of the corn is hogged down and very little is fed to cattle in the field.

Oats occupy the second largest acreage in the county and they are second in value. Average yields were reported in 1921 at 25 bushels. Ordinarily the yield ranges from 40 to 50 bushels on the better soils in favorable seasons. Both early and late varieties are grown. Iowa 103, Kherson, Early Champion and Iowa 105 are the leading early varieties. The late varieties include Silver Mine, Green Russian and Swedish Select. The crop is sown on corn land, after disking and from 75 to 90 percent of the acreage in corn one year is sown to oats the next. A large part of the crop is sold at the local elevators and disposed of on the Chicago and St. Paul markets.

Hay is the third crop in acreage and value. About one-fifth of the hay crop consists of wild hay, most of which is obtained from low, uncultivated areas of Webster silty clay loam. Timothy and clover make up the chief hay crop at present and average yields amount to 1.4 tons per acre. Some timothy is grown separately, both for seed and for hay. A small acreage is in clover alone, most of it being grown for seed. Most of the hay crop is used for feed on the farms. A part of the crop is baled and shipped.

Potatoes are grown on a comparatively small area, with an average yield of

\*Iowa Yearbook of Agriculture 1921.

34 bushels. Early Ohio, Rural New Yorker, Irish Cobbler and Burbank are the most popular varieties. Potatoes are raised for seed on a small area. In general the crop is utilized mainly for home consumption, the small surplus being disposed of on the local markets.

Barley is grown on a small area with yields of 28 bushels per acre, on the average. Most of the crop is fed, very little being shipped to outside markets. Wheat is a minor crop now, spring wheat being grown almost exclusively. The average yield is 13 bushels per acre. Marquis and Little Bluestem are the common varieties. Rye is a minor crop. Millet is grown on a small acreage and some sorghum is raised.

Alfalfa is grown successfully on some areas and average yields of 3.66 tons per acre are secured. Seed of the Grimm variety from Dakota and Minnesota is commonly used. This crop will undoubtedly be more generally grown as more is learned regarding its value and the methods which should be followed to secure a good stand. Sweet clover is grown on a few farms for hay and pasture. Soy beans are being grown to some extent for forage and silage. Ito San, Manchu and Black Eyebrow seem to be the best varieties. The medium green and yellow are best for silage purposes.

Sugar beets are being grown on a considerable area. The heavier black Webster soils, chiefly the silty clay loam and the loam, have proved best for this crop. Average yields of 10 to 14 tons per acre are secured. Areas of peat are now being used for beet growing and good yields are secured. Trucking is not practiced to any extent in the county. Vegetables are grown mainly for home use. Sweet corn is grown on small areas over the county.

Some fruit is grown on practically every farm, chiefly for home consumption. Orchards usually contain 10 to 20 trees but lack of care makes the yields low. Besides apples, some plums, cherries and pears are grown. The local markets are generally supplied with fruit from outside sources. Some strawberries, gooseberries, blackberries, raspberries and grapes are grown, but only for home use.

#### WRIGHT COUNTY'S LIVESTOCK INDUSTRY

The livestock industries of the county include the raising and feeding of hogs, the raising and feeding of cattle, sheep raising, horse raising and some dairying. The extent of the livestock industries in the county is shown by the following figures from the Iowa Yearbook of Agriculture for 1921:

Horses, all ages .....	12,869
Mules, all ages.....	527
Swine, on farms, July 1, 1921.....	91,144
Swine, on farms, Jan. 1, 1922.....	65,289
Cattle, cows and heifers kept for milk.....	10,027
Cattle, other cattle not kept for milk.....	22,908
Cattle, all ages .....	32,935
Sheep, all ages on farms Jan. 1, 1922.....	3,324
Sheep, shipped in for feeding 1921.....	1,761
Sheep, total pounds wool clipped.....	19,764
Poultry, total number on farms Jan. 1, 1922.....	234,484
Poultry, number dozen eggs received 1921.....	860,569

The raising of hogs is the most important livestock industry. The most popular breeds are the Poland China, Duroc Jersey and Chester White. However, mixtures of these breeds predominate. There are only a few purebred herds in the county. Several carloads of stock hogs are shipped in annually from Omaha and Sioux City for fattening. Most of the hogs are marketed in Chicago and St. Paul, a few going to Omaha. The larger feeders ship direct to the markets but most of the hogs are handled by local buyers and shipping associations at Clarion and Goldfield.

The beef cattle industry is second only to hog raising. Most of the cattle raised are grade Shorthorns; a few are grade Angus. There are a number of purebred herds in the county. Polled and Horned Hereford, Aberdeen-Angus, and Shorthorn breeds are most common. Purebred sires are maintained on practically all farms where cattle are raised. Many cattle, chiefly western feeders are shipped in for feeding.

A few colts are raised each year on most farms to supply the farm needs. Eight to 12 horses are usually kept on the farms. A few pure bred Percherons, Shires and Belgians are raised. Sheep are raised on a few farms and some are shipped in for feeding. There are a few pure bred Shropshires, Oxfords and Southdowns but most of the sheep are grades. The sheep industry is not extensive.

Dairying is of minor importance, just about enough milk and cream and dairy products being produced to supply the home demand and the local markets. Co-operative creameries are located at Clarion, Belmond, Goldfield and Eagle Grove. There are a few pure bred herds but most of the cattle are grades, Holstein, Shorthorn, Jersey or Guernsey.

The poultry industry is coming to be of more importance and flocks are maintained on practically every farm, many of them purebred. Considerable income is derived from the sale of poultry and poultry products, marketed thru local buyers who ship to the larger markets.

The value of land in Wright county is quite variable, depending on the location with reference to railroad facilities and to town, the improvements on the farms and the soil and topography conditions. The average value of well improved land ranges from \$200 to \$300 per acre. Poorly drained areas and sandy soils are lower in value and in some instances higher values are placed upon well improved farms.

#### THE SOIL FERTILITY SITUATION IN WRIGHT COUNTY

The crop yields secured in Wright county are generally fairly satisfactory but increases might be secured in some cases thru proper methods of soil treatment. In many cases the soil is not properly drained and in such instances crop yields are not as large as they might be. Tiling out land which is too wet is distinctly profitable. It is particularly important in Wright county that sufficient tile of ample size be provided to carry away excess moisture from level, poorly drained areas. The Webster types are most in need of drainage among the upland types, but some of the terrace and bottomland soils are also in need of drainage.

Some of the soils in the county are acid in reaction and in need of lime. The Webster types are usually well supplied with lime, but the Carrington types are



lacking. It is important, therefore, that the soils of the county be tested for acidity and, when acid, lime should be used in the proper amount, if the best growth of legumes is to be secured. Carrington and Clarion soils on the uplands, O'Neill, Buckner, Waukesha and Bremer soils on the terraces and Wabash soils on the bottoms are generally in need of lime. Sometimes the Webster soils are acid in the surface soil but they are well supplied in the subsoil.

Many of the types found in Wright county are black in color and high in organic matter and nitrogen but in several cases the soils do not contain adequate amounts of these constituents. In all cases, methods should be adopted which would permit of keeping up the supply. Farm manure is a very important fertilizer on many of these soils and gives large increases in crop yields. This material should be used on all farms, application being made to the lighter colored soils most in need of organic matter. On the darker soils applications should not be made preceding the small grain crop, owing to the danger of causing it to lodge, but even on these types small amounts applied at other points in the rotation give large effects on crops. The proper care and application of farm manure to Wright county soils will do much to make them most productive and keep them so. Legumes may be used as green manures in some cases and profitable results secured. The handling of the legume crop in the rotation in such a way that it serves at least as a partial green manure is very desirable. This may be accomplished by removing only one cutting of the clover the remainder being plowed under or better still by removing only the clover seed. The proper utilization of all crop residues is also important in order to keep up the supply of organic matter in these soils. The nitrogen supply may be maintained by the proper use of the farm manure and by supplementing this material with leguminous green manures.

The phosphorus supply is low in the soils of Wright county and it will be necessary to use phosphorus fertilizers at some time in the near future even if they do not prove of value now. There are evidences, however, from experiments and farm experience that phosphorus may give profitable returns in many cases at the present time. Definite recommendations cannot be made along this line as yet and neither can it be said whether rock phosphate or acid phosphate should be employed. Tests are under way, using these two materials, and eventually it will be possible to suggest the use of one or the other material under certain soil conditions. For the present it can merely be urged that farmers test both materials on their own soils and thus determine for their particular conditions, whether or not phosphorus is needed and which fertilizer will give the largest effects. Tests may be made on small areas, with little difficulty and the evidence points to a possibility of profitable crop increases.

Little erosion occurs in the county but washing occurs in some areas and where this is true, some method should be followed to prevent serious injury to the land.

## THE GEOLOGY OF WRIGHT COUNTY

The bedrock underlying the soils of Wright county is of no significance from the agricultural standpoint, as deposits of drift material have buried it deeply and the soils of the county are derived entirely from the drift material.

Three great glaciers swept over the county during the glacial age and each upon its retreat left behind a vast amount of debris or glacial till. The material left by the first two glaciers was later entirely removed by the action of streams and by the third glacier. Small scattered beds of gravel are all that remain of the early deposits. The third glaciation, known as the Wisconsin, left behind it a thick deposit from which the soils of the county have been formed. In its native condition, it is a yellow or gray compact mass of clay, sand, silt, gravel and boulders. In texture, the unweathered material is usually a clay containing much sand, small stones and some boulders.

Since its deposition, the drift deposit has been much modified by weathering, cropping and stream action, but there has been much less erosion and change in surface character than in the case of the earlier deposits of the Iowan glacier which make up the soils of counties to the east. The smooth topography, high moisture supply and poorly drained areas have led to large accumulations of organic matter from the heavy growth of vegetation which has occurred, and consequently the soils are typically dark-brown to black in color. The same factors which brought about a heavy growth of vegetation and prevented forest growth, have kept the decomposition of organic matter at a low point and prevented losses of plant food. Hence the soils are higher in plant food and lime as well as higher in organic matter than those types, formed from earlier glacial deposits. The poor drainage of the area has been a most important factor in the soil formation. It also explains the areas of peat and muck which are found in the county. The heavy, impervious clay subsoil has also played a part in the accumulation of organic matter from plant remains.

In the eastern part of the county there occur what are called the morainic hills. These mark the edge of the glaciation and are characterized by accumulations of sand, gravel and boulders in much larger amounts than in the typical drift. Pockets of these coarse materials occur on the tops of elevations and beds of gravel outcrop in places on the steeper slopes. These gravel outcrops are indicated on the map. The topography of this morainic area is very different from that of the typical level Wisconsin drift plain, and consists of elevations or rounded hills extending well above the level of the surrounding land.

#### PHYSIOGRAPHY AND DRAINAGE

There are two distinct topographic divisions of the county. A line drawn from the center of the northern boundary to a point five miles west of the southeastern corner of the county roughly divides the drift plain to the west from the morainic hills to the east. The drift plain has a nearly level to gently undulating topography. Boone river and its few tributaries have eroded the surface very little and flow thru narrow channels. Many flat areas with no natural drainage are common. Intermittent drainage channels are few.

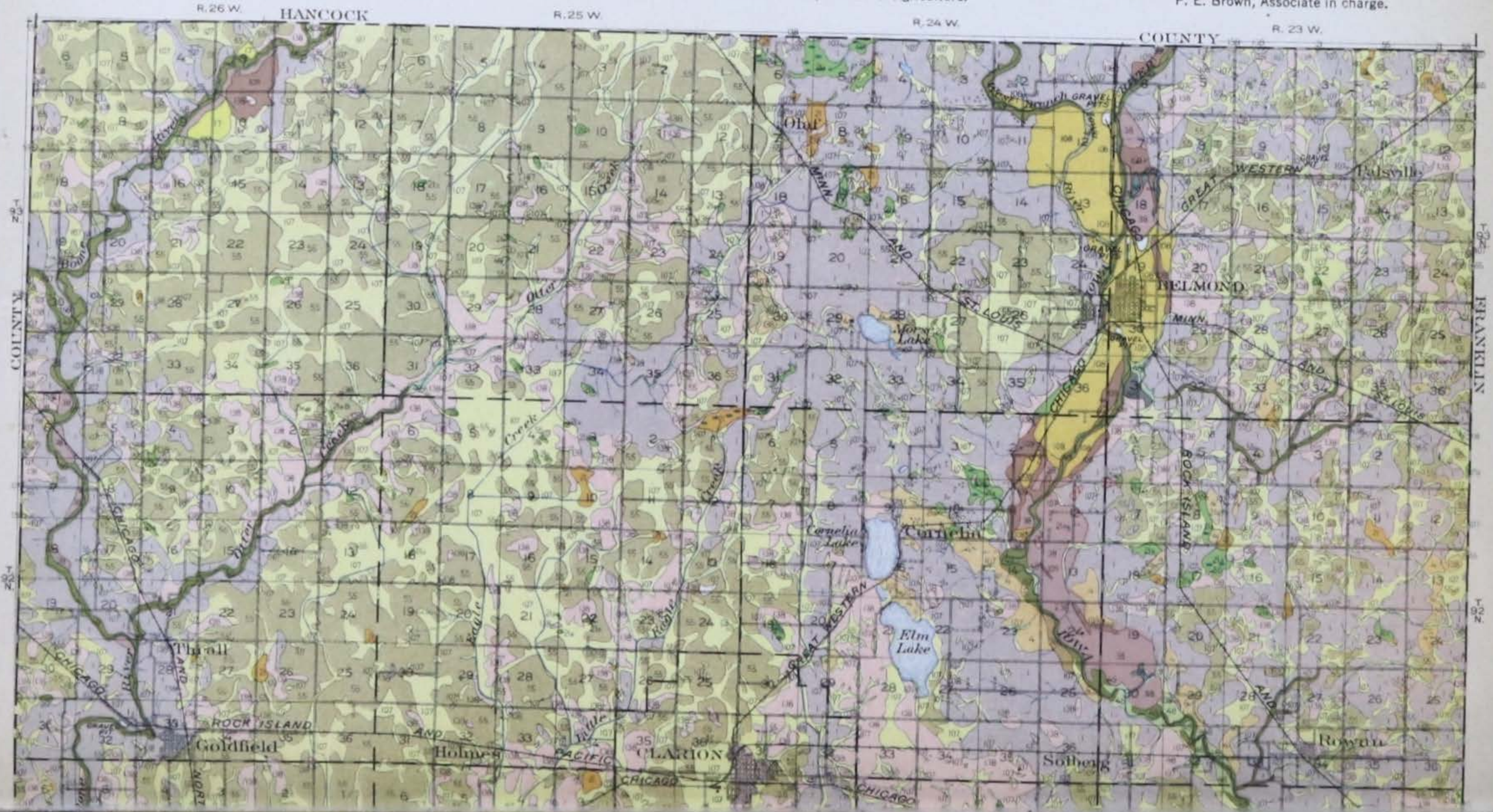
The morainic area consists of a gently to sharply rolling plain, cut by chains of morainic hills. One of these is found northeast of Clarion along the eastern side of Elm and Cornelia lakes. A small chain branches from this range and extends south about seven miles passing two miles east of Clarion. Another chain branches off west of Dows and extends in a northeasterly direction to the county line. Near Dows there are some isolated hills or mounds which rise 40

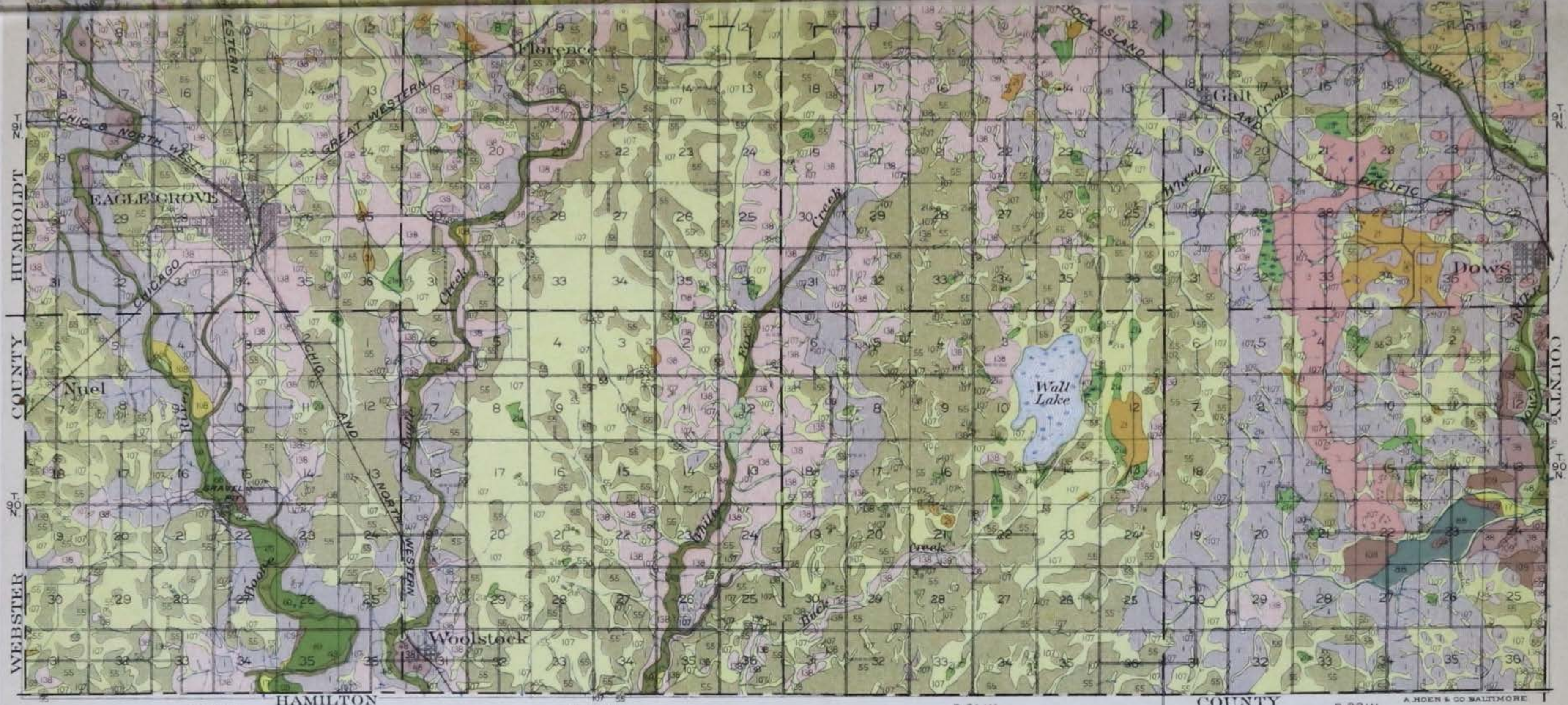
# SOIL MAP OF WRIGHT COUNTY

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

Thomas D. Rice, Inspector, Northern Division.  
Soils surveyed by T. H. Benton, of the Iowa Agricultural Experiment Station,  
in charge, and C. O. Jaeckel of the U. S. Department of Agriculture.

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





- DRIFT SOILS**
- 107 Webster silty clay loam
  - 55 Webster loam
  - 138 Clarion loam
  - 1 Carrington loam
  - 3 Carrington sandy loam

- TERRACE SOILS**
- 4 Carrington fine sandy loam
  - 108 O'Neill loam
  - 38 Buckner loam
  - 109 Fargo silty clay loam
  - 60 Waukesha loam

- SWAMP AND BOTTOMLAND SOILS**
- 88 Bremer silt loam
  - 17 Fargo loam
  - 49 Wabash loam
  - 21<sup>M</sup> Muck
  - 21 Peat
  - 48 Wabash silty clay loam

Scale: 1 inch = 2½ miles

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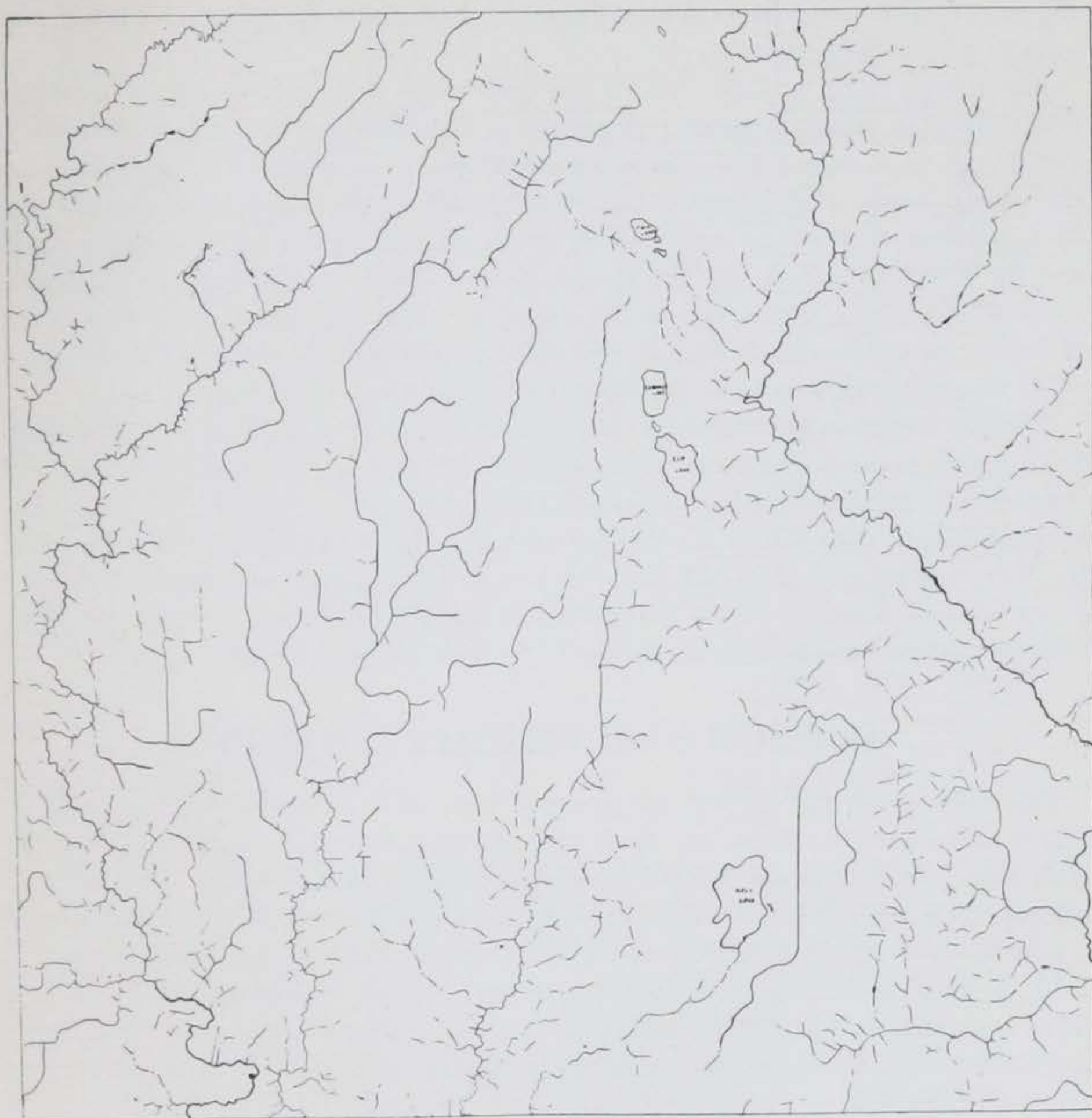


Fig. 3. Map showing natural drainage system of Wright county.

or 50 feet above the plain level. Marshes and sloughs occur among the hills but there are no drainage channels to bring about erosion. Probably one-third of the total area of the morainic region is flat and lacking in drainage outlets.

A chain of shallow lakes extends north and south across the county a little east of the center. These lakes vary in size from 320 to 1200 acres. Morse, Cornelia and Elm lakes are in the morainic region, while Wall lake is in the level prairie area.

The drainage system of the county is poorly developed as is indicated by the drainage map. Two rivers and their tributaries carry all the drainage water. The northern and eastern parts of the county are drained by the Iowa river and its tributaries. It enters the county four miles north of Belmond, and following a southeasterly direction leaves the county one mile north of Dows. It reenters just south of Dows flows along the county line for about three miles and then turns eastward. The flood plain of this river ranges from a few hundred feet to three-eighths of a mile. The West Branch of the Iowa river enters

the county five miles northwest of Belmond and joins the main stream one-half mile north of Belmond.

The Boone river with its tributaries drains the county west of the morainic hills. It is a sluggish stream meandering thru bottomlands from 20 feet to one-fourth of a mile wide. There are short gentle slopes to the uplands along the upper course of the stream, but where it leaves the county the uplands rise 50 to 60 feet with steep walls. Otter creek, White Fox creek and Eagle creek are the chief tributaries of the Boone river. They have narrow bottomlands, from which gentle slopes rise to the uplands. The land drained by the Boone river and its tributaries is confined to adjacent areas small in extent, as in many cases the topography is such that the drainage is away from the streams.

There has been much artificial drainage in the county, about a million dollars having been expended upon it. The tributary streams have been straightened and deepened by dredging, open ditches have been dug and large concrete mains have been installed. The fall in the ditches averages about one foot to the mile. Tile has been extensively installed, with outlets in the ditches, and there is usually a continuous flow of water which keeps the ditches open. There are still sloughs and depressed areas in the county which are not drained.

## THE SOILS OF WRIGHT COUNTY

The soils of Wright county are grouped into three classes according to their origin and location. These are drift soils, terrace soils and swamp and bottomland soils. Drift soils are formed from the materials carried by glaciers and left behind upon their retreat. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the stream which deposited them or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low poorly drained areas, along streams, and subject to overflow. The extent and occurrence of these groups of soils in Wright county are shown in table II.

The major portion of the county is in upland and the upland soils are all of drift origin. Hence 92.5 percent of the soils of the county are in the drift group. Terraces occur only along the Iowa river, the west branch of the Iowa river, the Boone river and a small tributary stream which enters the Iowa river, about 3½ miles south of Dows. The terraces vary in width ranging from one-eighth of a mile to 3 miles. The total area in terrace is 3.5 percent of the county.

First bottoms occur along all the main streams and for distances from one to five miles along their tributaries. They range from 50 feet to three-eighths of a mile in width. These bottomlands with the areas of peat and muck which are important, make a total of 4.0 percent of the county.

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

Soil Group	Acres	Percent of total area of county
Drift soils .....	340,672	92.5
Terrace soils .....	13,056	3.5
Swamp and bottomland soils .....	14,272	4.0
Total .....	368,000	....

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN WRIGHT COUNTY, IOWA

Soil no.	Soil type	Acres	Percent of total area of county
DRIFT SOILS			
107	Webster silty clay loam .....	108,736	29.5
55	Webster loam .....	92,288	25.1
1	Carrington loam .....	81,216	22.1
138	Clarion loam .....	51,264	13.9
3	Carrington sandy loam .....	3,648	1.0
4	Carrington fine sandy loam.....	3,520	0.9
TERRACE SOILS			
108	O'Neill loam .....	4,608	1.2
38	Buckner loam .....	4,416	1.2
109	Fargo silty clay loam.....	1,984	0.5
60	Waukesha loam .....	960	0.3
88	Bremer silt loam .....	704	0.2
17	Fargo loam .....	384	0.1
SWAMP AND BOTTOMLAND SOILS			
49	Wabash loam .....	6,848	1.9
21a	Muck .....	2,944	0.8
21	Peat .....	2,432	0.7
48	Wabash silty clay loam.....	1,856	0.5
...	Gravel pits .....	192	0.1
	Total .....	368,000	....

There are 14 soil types in the county and areas of peat, muck and gravel pits making a total of seventeen soil areas. There are six drift soils, six terrace types, and five areas of swamp and bottomland soils. These soils are distinguished on the basis of certain characteristics which are described later in this report. The areas of the different soil types in the county are shown in table III.

The Webster silty clay loam is the most extensive soil in the county, covering 29.5 percent of the total area. The Webster loam is second, covering 25.1 percent. The Carrington loam is somewhat smaller, covering 22.1 percent. The Clarion loam is still smaller, covering 13.9 percent. These four types cover over 90 percent of the county and are by far the most important soils. The Wabash loam, the largest bottomland soil, covers only 1.9 percent of the county and the O'Neill loam, the most extensive terrace type, covers only 1.2 percent. The Buckner loam is similar in area, covering 1.2 percent. The Carrington sandy loam and the fine sandy loam are both small in area, covering 1.0 and 0.9 percent respectively. The remaining types are all minor in area, covering less than 1 percent of the county.

There is some relation of the various soil types to the topographic features, particularly on the uplands. The Webster soils occur on level to flat areas while the Clarion and Carrington soils are found on the more rolling areas. The terraces and bottomlands are generally level in topography but there are some differences which are reflected in the soil type separations. Thus the Fargo soils occur in depressed areas while the O'Neill and Waukesha types are older terraces, higher and somewhat eroded. The bottomland soils are level with topographic features developed only where the streams have altered their courses.

### THE FERTILITY IN WRIGHT COUNTY SOILS

Samples were taken for analyses from each of the soils in Wright county. The areas of muck and peat were not sampled, as analyses of these materials have often been made and they are much the same in all areas. The more extensive types were sampled in triplicate, but only one sample was taken from the minor types. Care was exercised in securing the samples that they should be thoroly representative and that variations due to abnormal local conditions or previous soil treatments should be avoided. The samples were drawn at three depths, 0-6 2/3", 6 2/3-20" and 20-40", representing the surface soil, the subsurface soil and the subsoil, respectively.

Analyses were run on all the samples for total phosphorus, nitrogen, organic carbon, inorganic carbon and limestone requirement. The official methods were employed for the phosphorus, nitrogen and carbon determinations and the Truog qualitative test was used for the determination of limestone requirement. The figures given in the tables are the averages for the results of duplicate determinations on all the samples of each type and they represent therefore the averages of four or twelve determinations.

#### THE SURFACE SOILS

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

The phosphorus content of the soils of the county is somewhat variable, ranging from 808 pounds per acre in the Waukesha loam up to 2,067 pounds in the Fargo silty clay loam. No relations are evidenced between the soil groups and the phosphorus supply, larger variations actually occurring within groups than between them. There does seem to be some relation to soil series, however. Thus the Webster soils are higher than the Carrington types. One of the Fargo soils is higher than the other terrace types, but the other is somewhat lower. This

TABLE IV. PLANT FOOD IN WRIGHT COUNTY, IOWA, SOILS  
Pounds per Acre of Two Million Pounds of Surface Soil (0-6 2/3")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
DRIFT SOILS						
107	Webster silty clay loam....	1,791	10,000	107,149	24,000	0
55	Webster loam .....	1,158	6,960	82,719	0	2,000
1	Carrington loam .....	896	3,050	36,882	0	3,000
138	Clarion loam .....	1,091	5,000	60,060	0	2,000
3	Carrington sandy loam....	1,024	2,740	30,977	2,820	0
4	Carrington fine sandy loam.	943	2,740	37,401	0	3,000
TERRACE SOILS						
108	O'Neill loam .....	1,226	4,540	54,818	0	5,000
38	Buckner loam .....	1,131	3,980	52,962	0	4,000
109	Fargo silty clay loam.....	2,067	8,940	102,819	23,580	0
60	Waukesha loam .....	808	2,020	26,481	0	4,000
88	Bremer silt loam.....	1,158	5,960	75,784	0	5,000
17	Fargo loam .....	902	5,680	75,238	0	3,000
SWAMP AND BOTTOMLAND SOILS						
49	Wabash loam .....	1,455	6,800	79,770	0	2,000
48	Wabash silty clay loam....	1,563	9,500	129,354	0	1,000



indicates the influence of soil texture, for while the Fargo silty clay loam is the highest in phosphorus, the Fargo loam is lower than some of the other terrace loams. The topographic position of the soil undoubtedly has some effect on the phosphorus supply and the color is also of significance. Thus the level black Webster soils are higher than the rolling, dark brown Carrington and Clarion. But the soil texture always plays an important part in fixing its composition, and as noted in the case of the Fargo loam, may be the controlling factor. There are some evidences of texture effects in the same soil series. Thus the Webster silty clay loam is higher than the loam, the Fargo silty clay loam is higher than the loam, the Wabash silty clay loam is higher than the loam, the Carrington sandy loam is higher than the fine sandy loam. From these indications and from the results noted in other counties the conclusion may be reached that soils, heavy in texture will run somewhat higher in phosphorus than soils coarser in texture. It should be noted also that soils level to flat in topography, poorly drained and black in color, run higher than lighter colored soils, rolling in topography. Thus it would be expected that black silty clay loams on level areas would be higher in plant food constituents than silt loams, loams or sandy loams and these often grade in the order mentioned.

Considering the analyses of all the soils it seems evident that the phosphorus supply is not high enough in any case, but that phosphorus will be needed on the soils in the near future and may be of value at the present time. When the phosphorus content of soils is low there is sure to be a slow production of the element in an available form. Even where the supply is considerable, there may not be enough phosphorus changed to an available form to supply crop needs. As the total supply decreases, however, there is a more rapid reduction in availability. Hence it seems quite possible that many of the soils in Wright county may need available phosphorus, even where the total supply is better. But in all cases, systems of permanent fertility must plan on applying phosphorus. There is evidence from experimental data that phosphorus may be used profitably on some of the soils in the county at the present time. Whether acid phosphate or rock phosphate should be employed must, however, be determined for each individual condition. The former will supply the need of the element in an available form while the latter will build up the total supply. That material should be used, however, which will give the best crop effects and as these vary on different soils, tests must be made on the farms on small areas in order to be sure that the results will be profitable when applications are made to large areas.

The nitrogen content of the soils of the county is variable, ranging from 2,020 pounds in the Waukesha loam up to 10,000 pounds in the Webster silty clay loam. As noted in the case of phosphorus, there seems to be no relation between the soil groups and the nitrogen supply, altho the bottomland and terrace types seem to average slightly higher than the uplands. The differences, however, are slight. There does seem to be some relationship to the soil series, a reflection of those characteristics upon which series separations are based. The Webster soils, for example, are much higher than the Carrington or Clarion types, the Fargo soils are higher than the O'Neill, Buckner and Waukesha types and the

Bremer soils are much the same as the Fargo. There is some relation apparently of the origin, topographic position and soil characteristics to the nitrogen supply. Thus level to flat soils, poorly drained and black in color are higher in nitrogen than those which are rolling in topography, lighter in color and better drained. This might be expected as the latter types would have lost more nitrogen by drainage and by greater utilization by crops.

There is a rather definite relation between the texture of the soil and the nitrogen content. The Webster silty clay loam, for instance, is higher than the loam; the Carrington loam is higher than the sandy loam or the fine sandy loam; the Fargo silty clay loam contains more nitrogen than the loam and the Wabash silty clay loam is better supplied than the loam. Apparently soils heavy in texture will contain more nitrogen than light textured types. The results secured in other counties confirm these conclusions and in general it seems that silty clay loams will be richer than silt loams, silt loams will surpass loams and the latter will be higher than sandy loams and so on until the sands are reached, which are the poorest in plant food. The nitrogen content of soils may be quite accurately indicated by the color, topographic position and texture. The color is the best indication and black soils may be safely considered to be well supplied, having in most cases more nitrogen than lighter colored types.

The soils of this county are not extremely low in nitrogen in any case and in a few instances there is a large amount present. Nitrogen must not be overlooked, however, in planning systems of permanent fertility. Nitrogen disappears from soils quite rapidly when they are well drained and heavily cropped and some means must be employed to keep up the supply. Farm manure returns much of the nitrogen removed by crops and hence should be carefully preserved and applied to soils to prevent unnecessary losses. On light textured, lighter colored types larger amounts should be employed to build up the supply. On the heavier types, the manure should not be applied preceding the small grain crop, owing to the danger of causing it to lodge. Small amounts may be applied to these types with profit, however, at other points in the rotation.

The use of legumes as green manures is a second means which may be followed to supply nitrogen. When well inoculated these crops take up nitrogen from the air and when turned under in the soil they increase the nitrogen content. On the grain farm the lack of farm manure makes it necessary to use legumes in this way, but it is often necessary also on the livestock farm to supplement manuring by judicious green manuring. Turning under a part of the legume crop in the rotation may serve as a partial green manuring and, if the crop is inoculated, may increase the nitrogen supply. Thoro utilization of crop residues will also aid in keeping nitrogen losses at the lowest point. Wright county soils may be built up in nitrogen as necessary and the supply may be kept up by proper manuring, green manuring and use of crop residues.

The organic carbon content of soils is always closely related to the nitrogen supply. Hence there is also a direct relation to color. Black soils are high in nitrogen and organic carbon and vice versa. Organic carbon measures the amount of organic matter but it also indicates the nitrogen. The organic carbon in the soils of Wright county varies in much the same way as the nitro-

gen. The amounts range from 26,481 pounds in the Waukesha loam up to 129,354 pounds in the Wabash silty clay loam. The latter contained slightly less nitrogen than the Webster silty clay loam but is higher in organic matter. Similar relations occur between the soil series and soil types and the amount of organic carbon as were noted in the case of nitrogen. The Webster soils are higher than the Carrington or Clarion types, the Fargo and Bremer soils surpass the other terrace types. The color, topography and drainage conditions evidently play a very important part in determining the content of organic matter. The texture of the soil is also important, and in the same series soils of fine texture are richer in organic carbon than coarse textured types.

The relationship between nitrogen and organic carbon indicates the rate at which decomposition is going on in the soil, and hence gives evidence of the rate of available plant food production. If the relation is not at the best, the change of unavailable to available plant food may be too slow. In most of the soils in Wright county, the relation between these two constituents is such that crops should be properly supplied with available food. In some cases however, an addition of organic matter would improve conditions. Thus in the Carrington loam the use of farm manure will be of special value and on the sandy types of this series also. On all the soils of the county however, farm manure brings about large increases in crop yields and this material should be used in order to keep up the supply of organic matter.

Organic matter disappears from soils more or less rapidly under continued cultivation and good drainage and the soils of Wright county will gradually lose their supply of organic matter if means are not followed to keep up the content. Besides farm manure which is the most important fertilizing material, green manures may be used and crop residues should always be utilized. On the grain farm green manuring is an essential practice but it may also be necessary on the livestock farm to supplement the use of farm manure. Care should be taken in Wright county, in spite of the very satisfactory content which is present in most cases, to see that the organic matter supply does not decrease and that farm manure, green manures and crop residues are properly utilized.

Three of the soil types in the county show inorganic carbon in the surface soil and in these cases there is of course no limestone requirement. Several of the types show inorganic carbon in the subsurface soils and subsoils and the surface soil shows only a slight acidity. The Webster soils are high in lime, generally throughout the soil section. The Fargo soils are likewise well supplied. The Clarion types contain lime in the subsurface and subsoil but may show slight acidity in the surface. The surface soil of the Carrington types and of the O'Neill, Buckner, Waukesha, Bremer and Wabash soils may however be acid and hence in need of lime. It is evident that these types in Wright county should be tested to determine their lime needs and if satisfactory crops of legumes are to be secured, lime must be added.

The figures given in the tables indicate the lime needs of the soils but they should not be considered to show the exact amount of lime which should be employed in any individual case. Soils vary widely in lime requirement and every soil should be tested before an application is made. The figures given indicate

that large amounts of lime are not necessary but farmers should have their own soils tested before they apply lime. Only in this way can they put on the proper amount. Small amounts of lime applied to the surface soil will often aid in securing a good stand of legumes and when the lower soil layers are well supplied the later growth of the legume will secure all the lime it needs. It is desirable that farmers in Wright county test their soils for acidity, and apply lime to get the best results from legumes and to insure the most satisfactory growth of all crops. The beneficial effects of lime on some of these soils have been shown in experiments and in farm experience and the material has been shown to be most profitable for use.

#### THE SUBSURFACE SOILS AND SUBSOILS

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

The lower soil layers in Wright county are not any higher proportionately in plant food constituents than the surface soils and hence the conclusions drawn regarding the needs of the soils are not materially modified by considering the analyses of the lower soil layers.

Several of the soils show lime in the lower soil layers and in the Webster, Clarion and Fargo soils, large amounts are present. In many cases the Webster and Fargo soils also have lime in the surface soils and hence on these types lime need not always be employed. On the Clarion soils, the surface may be acid and a small amount of lime may be of value in giving legumes a good start. Lime rarely moves upward in the soil and the amount in the subsoil will have little effect on the needs of the surface soil. In all the other types in the county, except the three series mentioned, lime does not occur regularly in the subsoil. It is found in individual cases as indicated in the tables but in general the soils

TABLE V. PLANT FOOD IN WRIGHT COUNTY, IOWA, SOILS  
Pounds per Acre of Four Million Pounds of Subsurface Soil (6 2/3'-20")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
DRIFT SOILS						
107	Webster silty clay loam....	2,964	11,260	127,210	39,920	0
55	Webster loam .....	1,616	8,080	87,652	800	0
1	Carrington loam .....	1,320	4,420	53,071	0	2,250
138	Clarion loam .....	1,734	6,600	62,886	30,480	0
3	Carrington sandy loam....	1,804	2,920	28,680	69,000	0
4	Carrington fine sandy loam.	1,832	3,480	43,570	0	3,000
TERRACE SOILS						
108	O'Neill loam .....	1,724	4,720	55,692	0	5,000
38	Buckner loam .....	2,154	4,800	54,600	0	4,000
109	Fargo silty clay loam.....	2,800	8,400	108,230	52,840	0
60	Waukesha loam .....	1,536	4,040	53,508	0	4,000
88	Bremer silt loam .....	1,590	8,880	113,568	0	5,000
17	Fargo loam .....	1,454	5,160	64,310	2,520	0
SWAMP AND BOTTOMLAND SOILS						
49	Wabash loam .....	2,154	8,080	93,366	0	2,000
48	Wabash silty clay loam....	2,398	9,760	178,542	0	0

TABLE VI. PLANT FOOD IN WRIGHT COUNTY, IOWA, SOILS  
Pounds per Acre of Six Million Pounds of Subsoil (20"-40")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
DRIFT SOILS						
107	Webster silty clay loam....	2,466	2,160	39,456	68,160	0
55	Webster loam .....	2,787	4,380	48,150	58,320	0
1	Carrington loam .....	1,839	3,130	40,541	0	2,000
138	Clarion loam .....	1,929	5,520	62,886	30,480	0
3	Carrington sandy loam....	2,547	1,680	4,883	133,200	0
4	Carrington fine sandy loam.	2,142	2,340	32,760	0	3,000
TERRACE SOILS						
108	O'Neill loam .....	2,100	2,160	28,665	0	2,000
38	Buckner loam .....	3,312	2,820	40,950	0	4,000
109	Fargo silty clay loam....	3,435	3,540	57,181	69,600	0
60	Waukesha loam .....	1,818	2,340	28,584	900	
88	Bremer silt loam .....	1,656	4,860	59,950	0	4,000
17	Fargo loam .....	2,586	3,540	45,656	49,020	0
SWAMP AND BOTTOMLAND SOILS						
49	Wabash loam .....	2,262	6,540	79,443	0	2,000
48	Wabash silty clay loam....	2,304	6,180	103,218	13,080	0

are acid. It is very desirable therefore in order to insure the best crop growth that all the soils in the county be tested for lime needs and that this material be applied as required. Tests should be made regularly in the rotation as lime gradually leaches out of soils and one application will not suffice for all time. Neither will a content of lime at present mean that the soils will never need any. Eventually all soils which are well drained and heavily cropped will lose lime and any system of soil management must include the use of this material whenever needed.

### GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Wright county with the idea of learning something regarding the needs of the soils, and the value of certain fertilizing constituents. These experiments were carried out on the Webster silty clay loam and the Carrington loam, two of the most important types in the county. In addition greenhouse tests on the Clarion loam and the Webster silty clay loam from Palo Alto county are included inasmuch as these types occur in Wright county and conditions are much the same in both counties.

The fertilizer treatments were the same in all the experiments, and included the application of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. These materials were applied in the same amounts in which they are employed in the field tests and hence the results secured may be considered to indicate the fertilizer effects which may be secured in the field. Manure was added at the rate of 8 tons per acre. Lime was applied when necessary, in amounts sufficient to neutralize the acidity of the soil and supply two tons additional. Rock phosphate was added at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of a complete commercial fertilizer at the rate of 300 pounds per acre.



Fig. 4. Clover on Webster silty clay loam.

Wheat and clover were grown, clover being seeded about one month after the wheat was up. In the tests on the Wright county soils, only the clover yields are given, as the wheat yields were not secured.

#### RESULTS ON WEBSTER SILTY CLAY LOAM

The results of the experiment on the Webster silty clay loam are given in table VII, the figures being the averages of the green weights of the clover on the duplicate pots. Manure brought about a distinct gain in clover, showing the effect which may result from the use of this material on a soil which is as well supplied with organic matter as the Webster silty clay loam. The sample used in the test was acid in reaction and the use of lime proved of value. This type is not usually in need of lime but when it is acid, lime is shown to be of value on the legume crop. The rock phosphate and acid phosphate both brought about crop increases, but the complete commercial fertilizer had no effect. Apparently phosphates may be needed on this soil and may bring about profitable crop increases. The results do not show definitely which phosphate should be employed and tests in the field are very desirable. These materials seem preferable to complete fertilizers.

#### RESULTS ON CARRINGTON LOAM

Table VIII gives the results secured on the Carrington loam. Again the application of manure proved of large value and field tests and farm experience confirm the desirability of applying liberal amounts of manure to this soil. Lime showed no effect in this test but in general field experience the use of lime on this soil when it is acid is very necessary. The rock phosphate and acid phosphate both gave distinct crop increases, the acid proving somewhat better

TABLE VII. GREENHOUSE EXPERIMENT, WEBSTER SILTY CLAY LOAM, WRIGHT COUNTY

Pot No.	Treatment	Weight green clover in grams
1	Check .....	61.23
2	Manure .....	108.86
3	Manure+Lime .....	127.00
4	Manure+Lime+Rock phosphate .....	140.61
5	Manure+Lime+Acid phosphate .....	131.54
6	Manure+Lime+Complete commercial fertilizer.....	124.74

TABLE VIII. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, WRIGHT COUNTY

Pot No.	Treatment	Weight green clover in grams
1	Check .....	68.04
2	Manure .....	108.86
3	Manure+Lime .....	104.32
4	Manure+Lime+Rock phosphate .....	113.40
5	Manure+Lime+Acid phosphate .....	122.47
6	Manure+Lime+Complete commercial fertilizer.....	138.34

than the rock. The complete fertilizer gave larger effects than the phosphates but it is doubtful if increases sufficiently larger than those brought about by phosphates would be secured in the field, to warrant the use of the more expensive complete brands. There is evidence of value from the use of phosphorus on this soil and it is very desirable that both rock phosphate and acid phosphate be tested on the farm to determine not only the need of phosphorus but also which material may be most profitably employed. Complete fertilizers may also be tested if desired and if they give more profitable returns than the phosphates, taking into account their greater cost, then they may be used without fear of injuring the soil.

CLARION LOAM RESULTS

The results obtained on the Clarion loam from Palo Alto county are given in table IX, the averages of both the wheat and clover yields being shown. Manure brought about distinct increases both in the wheat and in the clover. Lime with manure had no effect on either crop in this test. In general however when this soil is acid lime will give an increase at least in the legume crop of the rotation. Farm experience shows definitely the general need of testing this soil and of applying lime when it is distinctly acid.



Fig. 5. Wheat and clover on Clarion loam.

TABLE IX. GREENHOUSE EXPERIMENT, CLARION LOAM,  
PALO ALTO COUNTY

Pot No.	Treatment	Wt. wheat grain in grams	Wt. clover in grams
1	Check .....	9.5	56.69
2	Manure .....	14.5	68.04
3	Manure+Lime .....	14.0	68.04
4	Manure+Lime+Rock Phosphate .....	16.0	74.84
5	Manure+Lime+Acid phosphate .....	16.0	86.18
6	Manure+Lime+Complete commercial fertilizer.....	16.3	70.25

The phosphorus fertilizers both brought about increases in the two crops, the effects being particularly noticeable on the clover. On the latter crop the acid phosphate gave greater effects than the rock but no differences were secured on the wheat. The complete commercial fertilizer showed less effect than the phosphates on the clover but had about the same effect on the wheat. It is evident that phosphorus may be of considerable value on this soil but which phosphate fertilizer should be employed must be determined for individual soil conditions. The results will vary on different areas and acid phosphate may not show larger effects in all cases as it does on the clover in this test. It seems from these results that a complete commercial fertilizer would not prove as profitable as a cheaper phosphorus carrier.

## WEBSTER SILTY CLAY LOAM RESULTS IN PALO ALTO

Table X shows the results obtained on the Webster silty clay loam from Palo Alto county. The effects of manure on this soil type are shown in the results both on the wheat and on the clover. Apparently this material is desirable for use even on this type which is rich in organic matter. Lime increased both crops, indicating that when this soil is acid, it is very desirable to apply lime. The phosphates and the complete commercial fertilizer had some effects on the crops but only in the case of the acid phosphate on the wheat was the increase definite. Apparently phosphorus may be desirable for use on this soil in some cases and tests both of acid phosphate and rock phosphate are urged. The use of a complete commercial fertilizer seems less desirable than the application of a phosphate.

## FIELD EXPERIMENTS

Field experiments have been laid out in Wright county but they have not been under way long enough to permit of the securing of definite results. Such tests must be carried for several years before conclusions can be drawn from them. The data secured will be published later in a supplementary report. Some tests have been under way for several years in adjacent counties on the same soil

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

Pot No.	Treatment	Wt. wheat grain in grams	Wt. clover in grams
1	Check .....	26.56	29.5
2	Manure .....	29.46	36.0
3	Manure+Lime .....	31.71	44.0
4	Manure+Lime+Rock phosphate .....	28.95	46.0
5	Manure+Lime+Acid phosphate .....	35.80	45.0
6	Manure+Lime+Complete commercial fertilizer.....	31.13	46.0



types which occur in Wright county and the results thus far obtained are given here, inasmuch as they indicate the effects which may be secured from the same fertilizer treatments on the soils of this county. The data given are not as conclusive as they will be later after the tests have been carried for a longer time, but they do indicate how crop yields may be increased on certain soils and hence they are of some value and they will be discussed briefly. Experiments on the Webster silty clay loam in Buena Vista county on the Storm Lake Field and the Newell Field, on the Carrington loam in the same county on the Truesdale Field, and on the Webster loam in Webster county on the Lundgren Field, are discussed here. Average results secured on all the fields in the state on the Carrington loam are also given.

These field experiments are all located on land which is thoroly representative of the particular soil types. The plots are 155' 7" by 28' in size, making them one-tenth of an acre. They are permanently located by installing corner stakes and all precautions are taken in the application of fertilizers and in the harvesting of the crops to be sure that the results obtained are accurate. Tests are included on all the fields of the value of certain fertilizers under the livestock system of farming and under the grain system. In the former, manure is applied as a basic treatment while in the latter, crop residues are employed. Only the results under the livestock system are given here as the crop residue treatments have not yet shown definite effects.

Manure is applied at the rate of eight tons per acre, once in a four year rotation. Limestone is used in amounts sufficient to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is added at the rate of 2,000 pounds per acre, once in the rotation and acid phosphate at the rate of 200 pounds per acre annually. Until last year the old standard 2-8-2 complete commercial fertilizer was applied at the rate of 300 pounds per acre annually. Now the new standard 2-12-2 brand is employed at the rate of 267 pounds per acre, thus supplying an amount of phosphorus equivalent to that contained in the 200 pounds of 16 percent acid phosphate.

#### THE STORM LAKE FIELD

The results secured this far on the Webster silty clay loam on the Storm Lake Field in Buena Vista county are given in table XI.

Manure showed some effect on the corn in 1920 and again on the clover in

TABLE XI. FIELD EXPERIMENT, WEBSTER SILTY CLAY LOAM, BUENA VISTA COUNTY, STORM LAKE FIELD

Plot No.	Treatment	Oats, bu. per acre 1918	Corn bu. per acre 1919	Corn bu. per acre 1920	Oats bu. per acre 1921	Clover tons per acre 1922
1	Check .....	73.0	54.7	48.2	45.1	0.75
2	Manure .....	73.0	54.7	57.3	42.1	1.01
3	Manure+KCl (1921) (1922)....	73.0	57.6	58.1	....	1.29
4	Manure+Rock phosphate .....	80.6	61.1	64.2	43.8	1.26
5	Manure+Acid phosphate .....	74.5	66.4	76.5	51.7	1.42
6	Manure+Complete commercial fertilizer .....	82.0	61.1	80.0	43.8	1.43
7	Check .....	70.0	....	66.6	40.9	1.10

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

Plot No.	Treatment	Corn bu. per acre 1918	Corn bu. per acre 1919	Oats bu. per acre 1920	Clover 2nd cuttings lbs. per acre 1921	Corn bu. per acre 1922
1	Check .....	69.0	44.8	56.7	1050	68.7
2	Manure .....	70.9	49.1	64.1	1200	70.5
3	Manure+Lime .....	71.4	54.4	63.5	1400	69.9
4	Manure+Lime+Rock phosphate	74.1	61.4	69.7	1400	74.1
5	Manure+Lime+Acid phosphate	66.9	65.1	76.3	2250	80.0
6	Manure+Lime+Complete commercial fertilizer .....	66.4	70.9	68.9	2400	74.4
7	Check .....	60.9	62.4	59.4	1150	66.9

1922. Little effect was evidenced on the other crops. No lime was applied as the soil was not acid in reaction. The yield on the manure potash plot in 1921 is not given owing to very evident abnormality. Rock phosphate and acid phosphate gave increases in practically all cases, the acid phosphate showing up somewhat better than the rock, each year except 1918. The rock showed no effect on the clover and little on the oats in 1921. The gains from acid phosphate were pronounced in every instance except in 1918. The complete commercial fertilizer gave crop increases except on the oats in 1921. The results were sometimes better than those with acid phosphate but not in all cases. Fifty pounds of muriate of potash applied to Plot 3 in 1921 showed no effect but did increase the clover in 1922.

The data in general indicate that manure in small amounts may prove of some value on this soil. It should not be applied of course preceding the small grain crop. Phosphorus fertilizers may often prove profitable but tests are necessary on the farm to show whether rock phosphate or acid phosphate should be employed. The complete commercial fertilizer would not seem as desirable for use as a phosphate, owing to its greater cost, and to the fact that it does not give greater effects than the phosphates.

#### THE NEWELL FIELD

The results secured on the Webster silty clay loam on the Newell Field in Buena Vista county are given in table XII.

Manure brought about some crop increases in practically all cases. Lime applied in 1920 with manure showed some effects on the clover and corn. The rock phosphate and acid phosphate gave increases in all but one case, the acid phosphate proving superior to the rock each year after 1918. The complete commercial fertilizer gave increases in all cases except on the corn in 1918. The effects were sometimes greater than those of the acid phosphate and sometimes smaller. There is evidently no reason to expect as profitable results from complete fertilizers as from the phosphates.

The indications from the Storm Lake Field are confirmed by these results on the same soil type. Manure gives some effects, lime proves of value when needed and phosphorus fertilizers may give profitable effects. The indications are that acid phosphate would be preferable but tests should be carried out in the field before a choice of phosphates is definitely made.

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

Plot No.	Treatment	Corn bu. per acre 1918	Corn bu. per acre 1919	Oats bu. per acre 1920	Clover tons per acre 1921	Corn bu. per acre 1922
1	Check .....	38.9	56.5	57.2	1.40	48.6
2	Manure .....	44.3	57.1	57.9	1.20	61.6
3	Manure+Lime .....	46.4	58.1	59.2	1.60	64.0
4	Manure+Lime+Rock phosphate .....	54.4	58.7	64.7	2.45	63.2
5	Manure+Lime+Acid phosphate .....	49.6	58.7	64.9	3.30	61.6
6	Manure+Lime+Complete commercial fertilizer.....	49.6	58.7	64.7	3.10	63.7
7	Check .....	38.4	58.1	56.4	2.20	51.0

THE TRUESDALE FIELD

The data obtained on the Carrington loam on the Truesdale Field in Buena Vista county are given in table XIII for Series I.

The application of manure gave increases in crop yields in every case except on the clover in 1921. The yield on the manure plot that year was evidently abnormal and in general as will be noted later, manure shows distinct effects on clover. The effect of the manure is particularly evidenced on the corn in 1922. Lime with manure proved of value on all the crops, the beneficial effects showing on the corn and small grains as well as on the clover. The effects of rock phosphate and acid phosphate are evidenced particularly on the oats and clover. Little effects were secured on the corn, altho slight gains were noted in some cases. The acid phosphate seems somewhat better than the rock in some instances but the results are not definite enough to permit of conclusions. The complete commercial fertilizer had no better effects than the phosphates and hence could not be considered preferable.

The results on Series II on the same field are given in table XIV. The yields of oats in 1918 were very irregular and the clover in 1919 winter killed. The crops secured in 1920, 1921, and 1922 are given in the table.

Again there is evidence of value from the use of manure, increases being secured in both crops of corn and in the oats. Lime with manure gave a further increase in all cases. The phosphates both showed gains in practically all cases, there being very little choice between the two materials. The complete fertilizer showed very similar effects to those brought about by the phosphates.

The results of these two experiments on this field indicate that manure is a

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

Plot No.	Treatment	Corn bu. per acre 1920	Corn bu. per acre 1921	Oats bu. per acre 1922
1	Check .....	47.5	32.8	18.5
2	Manure .....	57.0	39.7	24.6
3	Manure+Lime .....	59.0	41.8	27.2
4	Manure+Lime+Rock phosphate .....	61.2	38.1	32.4
5	Manure+Lime+Acid phosphate .....	62.1	40.1	31.0
6	Manure+Lime+Complete commercial fertilizer.....	64.0	44.4	31.9
7	Check .....	57.1	36.2	23.6

TABLE XV. FIELD EXPERIMENT, WEBSTER LOAM, WEBSTER COUNTY, LUNDGREN FIELD

Plot No.	Treatment	Corn bu. per acre 1919	Corn bu. per acre 1920	Oats bu. per acre 1921	Corn bu. per acre 1922
1	Check .....	59.0	63.8	32.9	57.7
2 & 3	Manure .....	59.4	63.8	35.3	55.7
4	Manure+Rock phosphate .....	61.3	69.3	38.7	57.1
5	Manure+Acid phosphate .....	65.1	67.2	35.8	54.9
6	Manure+Complete commercial fertilizer....	65.1	74.2	36.6	57.5
7	Check .....	54.0	59.7	32.6	46.6

valuable fertilizer for this soil, and will exert a beneficial effect on all the crops grown. Lime should be applied when the soil is acid and gives beneficial effects. Phosphorus fertilizers seem to be of value on this soil and tests of acid phosphate and rock phosphate on small areas on individual farms are recommended. Complete fertilizers seem less desirable than phosphates.

#### THE LUNDGREN FIELD

Table XV gives the results obtained on the Webster loam on the Lundgren Field in Webster county. This soil was not acid and hence no lime has been applied and the results given in the table are averaged for plots 2 and 3. The yield of oats in 1918 is not given owing to irregularity in the results.

Manure shows only slight effects on this soil but farm experience has shown that it may give good results when not applied just before the small grain crop. The phosphates and the complete commercial fertilizer increased the crops to some extent, except in 1922 when small effects were obtained. The results are not definite enough to permit of a choice between the two phosphates but there is no evidence of sufficiently greater effects from the complete fertilizer to warrant its use. Small applications of manure are desirable on this soil to keep up its fertility and crop increases are usually secured from its use. Phosphorus fertilizers may be of value and tests of both rock phosphate and acid phosphate are very desirable.

#### AVERAGE RESULTS ON THE CARRINGTON LOAM

In table XVI the average results from all the field experiments on the Carrington loam are given. The check yields are the averages of all three check plot yields for each crop on all the fields.

The application of manure increased the yields of corn, oats and clover to a definite extent. Lime with manure gave further increases on the corn and oats as well as on the clover. The rock phosphate and acid phosphate both gave increases in the three crops the acid proving better on the clover, while the rock seemed somewhat preferable on the oats. The complete commercial fertilizer brought about effects which were very similar to those occasioned by the use of acid phosphate, proving slightly better on the oats but no better than the rock in the case of that crop.

Crop residues showed small effects on all the crops. Lime again produced increases which were very similar on the corn and oats. The rock phosphate and acid phosphate gave distinct increases on all crops, the acid phosphate being more effective in all cases. The complete fertilizer had more effects than the

TABLE XVI. CARRINGTON LOAM. AVERAGE CROP YIELDS AND INCREASES DUE TO FERTILIZER TREATMENTS, IOWA EXPERIMENT FIELDS

Treatment	Corn*		Oats*		Clover*	
	Av. yield, bu. per acre	Increase for treatment, bu. per acre	Av. yield, bu. per acre	Increase for treatment, bu. per acre	Av. yield, tons per acre	Increase for treatment, tons per acre
Check .....	51.9	.....	43.6	.....	1.25	.....
Manure .....	58.8	6.9	49.6	6.0	1.38	0.13
Manure+Lime .....	62.6	10.7	53.0	9.4	1.57	0.32
Manure+Lime+Rock phosphate...	66.0	14.1	62.3	18.7	1.97	0.72
Manure+Lime+Acid phosphate...	66.3	14.4	60.8	17.2	2.27	1.02
Manure+Lime+Complete commercial fertilizer .....	66.8	14.9	62.4	18.8	2.29	1.04
Crop residues .....	54.7	2.8	47.3	3.7	1.37	0.12
Crop residues+Lime .....	57.5	5.6	49.3	5.7	1.41	0.16
Crop residues+Lime+Rock phosphate .....	61.8	9.9	51.2	7.6	1.80	0.55
Crop residues+Lime+Acid phosphate .....	62.4	10.5	52.7	9.1	1.94	0.69
Crop residues+Lime+Complete commercial fertilizer .....	64.2	12.3	51.2	14.6	2.02	0.77

\*Corn yields averaged from 20 crops on 10 fields, oats from 9 crops on 5 fields and clover from 15 crops on 9 fields.

phosphates but they were hardly sufficiently larger to make the complete materials more desirable as they cost so much more than the phosphates.

It may be concluded from these average results that the Carrington loam will respond to applications of manure, lime and phosphorus. Liberal applications of manure will give large crop increases. Lime should be used in the proper amount on the soil when it is acid and profitable results will be secured on all crops. It seems evident that a phosphate fertilizer may prove of value and it is urged that rock phosphate and acid phosphate be tested on small areas to determine which material will give the best results. Complete commercial fertilizers cannot be recommended for use unless they have been tested in comparison with the phosphates and have been proven to give more profitable effects, taking into account the greater cost of the application.

### PEAT SOILS

Peat is partially rotted vegetable matter which consists either of swamp grass, sedges, rushes and flags, or of sphagnum moss; the former variety is known as grass peat and the latter as moss peat. Peat forms in swamps, marshes, or flat, undrained areas where water stands and water-loving grasses and mosses grow in profusion. The remains of such plants accumulate under water and the absence of air permits of only very incomplete decomposition. Deposits of peat thus formed increase from year to year and, with the long continuance of swampy conditions, may become of considerable depth. When the glacier which once covered north central Iowa retreated, the rather level Wisconsin drift soil area was left. Numerous depressions occurred in this area, especially near the edges, and in these places, because of the heavy, impervious character of the subsoil, lakes, ponds and marshes were formed and the formation of peat followed. It is mainly in the Wisconsin drift soil area, therefore, that peat occurs in Iowa.\*

\*Bull. Ia. Agr. Exp. Sta. 157—Improving Iowa's peat and alkali soils.

Wright county is located in this soil area and has several peat areas, altogether making a total of 2,432 acres or 0.7 percent of the total area of the county.

There are two classes of Iowa peats, the shallow and the deep. The latter have been mapped by the Iowa Geological Survey and their commercial value pointed out.\*\* They are composed of fibrous, fairly dry, vegetable matter extending from 5 to 15 feet in depth, and they need not be considered from the agricultural standpoint. The shallow peats are usually not over three feet in thickness and the reported experiments on peat soils have dealt only with the shallow peats. The suggestions and recommendations regarding the treatment of peat soils which are made in this report, refer, therefore, only to the shallow peats, and are not at all applicable to deep peats.

The peat in Wright county is generally from 10 to 14 inches in thickness and only in two or three localities does it extend to a depth of more than three feet. Practically all the peat soils in this county may be reclaimed and made productive by proper methods of treatment and cropping.

Analyses of numerous samples of peat soils showed that they contained not only an abundance of nitrogen and organic matter, but also considerable amounts of lime. Their phosphorus and potassium content was rather low, but these elements were abundant in the clay which forms the subsoils of practically all the shallow peats in Iowa. In Wright county, there are no areas where the subsoil under the peat is not a black to drab, plastic clay. The character of the subsoil plays a very important part, as will be seen in the treatments which are advised for the reclamation of peat soils. On this account, the heavy character of the subsoils underlying the peats in this county is emphasized.

Field experiments were carried out several years ago on some typical shallow peats near Somers, Eagle Grove and Ontario, in Webster, Wright and Story counties, and these tests were considered at length in the bulletin mentioned above. The tests included the use of gypsum, limestone, phosphorus and potassium, each applied alone or in combination, in the amounts in which such materials are generally applied to soils. In no cases were there any profitable increases in crop yields from the use of any of these materials and in most instances the variations in yields between the treated and the untreated soils were only such as might easily occur between duplicate plots.

It is apparent from the data given in those field experiments that the shallow peats in Wright county do not need the addition of commercial fertilizing materials to make them productive. Altho they are not high in phosphorus and potassium, applications of fertilizers containing these constituents do not seem to be necessary and crops seem able to secure a sufficient amount of these plant foods from the subsoil, which is well supplied with them. Furthermore, peat soils contain an abundance of nitrogen and organic matter and applications of manure are not advisable. Not only is it of no special value, but in many cases it increases the weed growth on the reclaimed peat to such an extent that it is almost impossible to control it. A small application may be of use on newly reclaimed peat by serving to introduce decay bacteria into the peat and increase the speed of decomposition. In general, manure should not be used on peat

\*\*Iowa Geological Survey 19: 168, 1908.

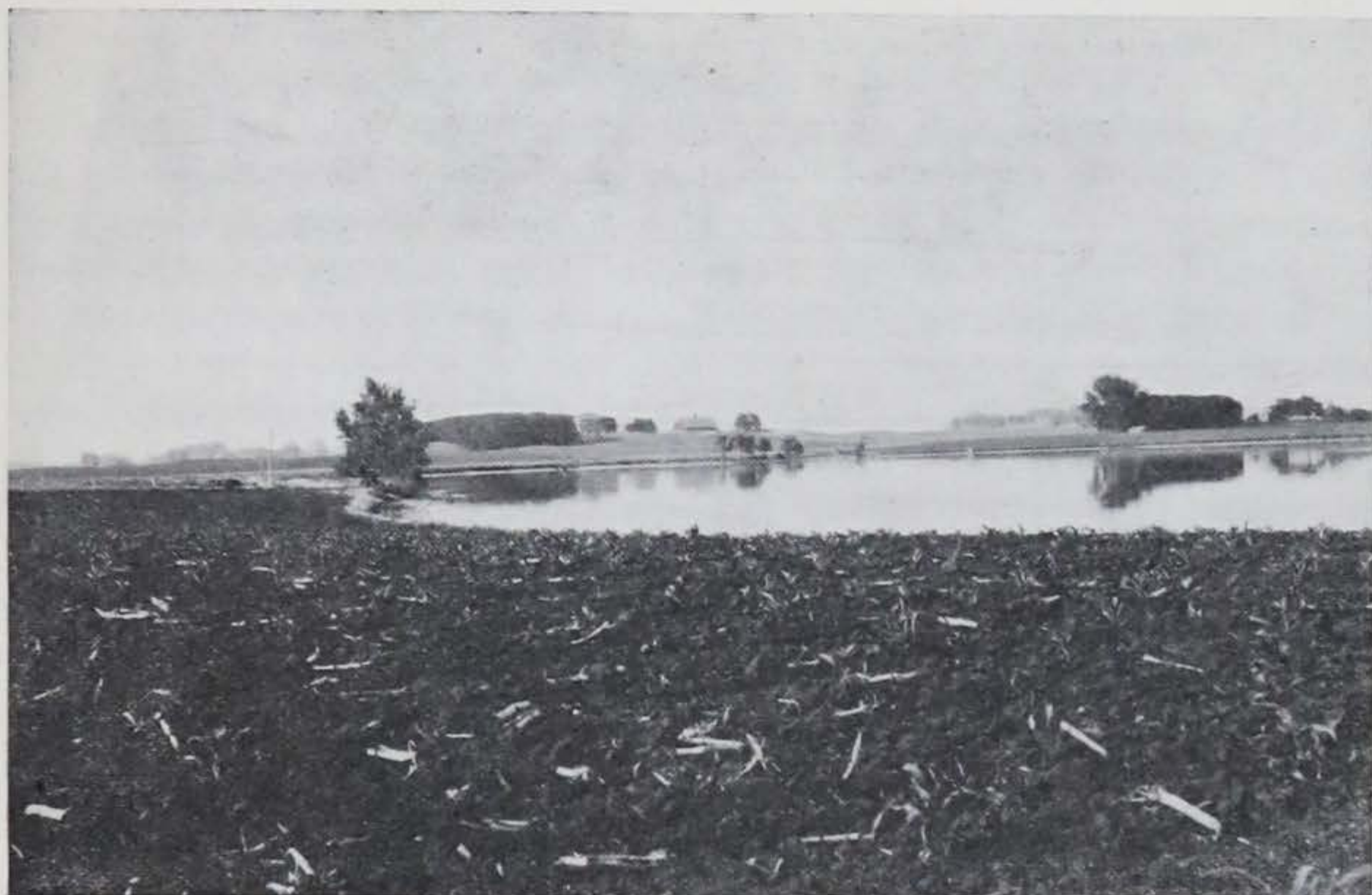


Fig. 6. Several lakes occur thruout the Morainic region.

soils, but should be utilized on land in greater need of organic matter and nitrogen.

#### DRAINAGE AND CULTIVATION FOR PEAT SOILS

What the peats in Wright county need to make them productive is the physical improvement resulting from drainage, cultivation and the growing of proper crops.

Drainage is the most important step. Sufficient tile of ample size and special drains to carry away flood waters and prevent the flooding of the low-lying peat areas at times of heavy rainfall, are essential. The tile in the drainage system should be laid in the underlying subsoil rather than in the peat itself, as in the latter case the compacting of the peat would bring the tile too close to the surface and re-laying would be necessary. The tile should not be laid too deeply in the subsoil, as the heavy clay is quite impervious to the passage of water. It is often advisable to cover the tile at points a few rods apart with straw, gravel, cinders or some other material which will allow for the ready passage of water into the drains.

Fall plowing is desirable for peat soils in order to expose the soil to the action of the frost, rain and snow during the winter and hasten the decay of the peat. Fall-plowed peats may be worked earlier in the spring, hence, the seed bed may be more thoroly prepared. Deep plowing is also valuable, especially when the peat is very shallow and some of the underlying, heavy clay, rich in phosphorus and potassium, may be mixed with the peat. The physical and chemical conditions of the peat are both much improved by such a mixing and crop production is increased. Even in the case of deeper peats, where the subsoil is not reached

by the plow, it is of advantage to plow to a considerable depth in order to open up the peat to the action of the air and thus hasten decomposition.

Iowa peat soils which are not over 16 inches in depth should not be rolled, as such an operation may compact them too much and check decomposition of the peat. Where the peat is deeper than this, careful rolling may be of value in providing a firmer seed bed, but the practice cannot be generally recommended.

The frequent cultivation of peat soils is very important in opening them up and hastening decay of the organic matter. Furthermore, the growth of weeds is kept in check by cultivation, a fact which is particularly important on newly reclaimed peat, as the weed growth is apt to be luxuriant and interfere seriously with the production of crops.

Corn and small grain crops, as a rule, do not do well on newly reclaimed peat soils. The corn may not mature and the small grains may develop an abundance of straw and little grain. Therefore, it is not advisable to seed these crops on peat soils until several years after their reclamation, when the organic matter has reached an advanced state of decomposition.

A mixture of timothy and alsike clover is probably the best crop to seed on newly reclaimed peat land. It may be cut for hay, but it is better used as pasture, as the trampling by the stock compacts the peat and aids in its decomposition. A number of Iowa farmers who have used this crop in this way report a rapid decay of the peat and reclamation within a few years.

Many vegetables have been grown satisfactorily on peat soils. Onions, celery, tomatoes and potatoes all gave excellent results on the experiment plots near Ontario. Cabbages, beets, turnips and other crops might also prove of value. The use of such crops on newly reclaimed peat soils should be encouraged.

After a few years of pasturing or growing truck crops, peat soils are usually in a condition which will permit of the successful growth of corn and small grain crops. When properly reclaimed, peat soils may become extremely productive and it is certainly advisable to attempt the utilization of the peat areas in Wright county. With proper treatment and crop growth, they can be reclaimed.

### “ALKALI” SOILS

So-called “alkali” spots may frequently be found on farms located in north central Iowa in the Wisconsin drift soil area. They are mainly associated with peat deposits and vary in size from one-tenth of an acre to two acres.

There are several areas of alkali soils in Webster county and while their extent on individual farms is small, they seriously reduce crop yields and present a difficult problem in management.

Such alkali spots are characterized by a whitish deposit of salts on the surface of the soil, giving the ground the appearance of having been lightly strewn with a fine white powder. Corn produces only a stunted growth on such spots while other crops are affected to less extent.

The origin of these spots has been discussed in another publication.\* They occur in connection with swales, ponds, or sloughs which have recently been drained. They are not found in the lower parts of the slough but always in a

\*Bull. Ia. Agr. Exp. Sta. 157—Improving Iowa's peat and alkali soils.



belt around the low spot, which frequently consists of peat, and they do not appear until after the area has been drained.

The character of the accumulation of so-called "alkali" salts in such localities has been considered in the bulletin mentioned and more in detail in a later publication\*\* and it is apparent from the studies which have been carried out that the salts which occur are quite variable. The chief constituent is calcium bicarbonate, which is carried in solution in the soil water and deposited on the surface as calcium carbonate. A variety of other salts is also common to the Iowa "alkali" soils, magnesium carbonate, nitrates, sulfates and the carbonate and bicarbonate of sodium being frequently found. The amount of these latter salts which make up the "alkali" content of Wright county "alkali" soils, are insufficient alone to cause injury to crops. Their presence, however, with the excess of calcium bicarbonate which always occurs, may prove injurious.

The "alkali" problem in Wright county and in Iowa in general is therefore less serious than in the west and reclamation of affected soils is more readily accomplished.

#### TREATMENT FOR ALKALI SOILS

The first treatment necessary for the reclamation of alkali soils in Iowa is proper drainage. Alkali spots do not appear until after a soil is drained but this does not mean that the drainage produces the alkali conditions. A large amount of salts was present prior to drainage and the excess water merely concealed the high content. Thoro drainage is essential for the removal of alkali salts from the soil and in draining a slough or pond, lines of tile should be laid around the low area as well as through the center. These two lines will then run thru the area where the alkali is most likely to appear and the washing out of any excess of salts will be much more rapid. The lines of tile may be brought together again below the slough and if the area is rather wide, a third line of tile through the center of the slough may be advisable.

If tile is properly laid when a pond or slough is to be drained, the occurrence of alkali spots may frequently be prevented. When the alkali spot is fully developed, as is frequently the case in Wright county, the removal of excess salts by proper drainage of the area is hastened considerably by the application of heavy dressings of farm manure. Straw or any kind of vegetable matter plowed under will also aid in the rapid removal of salts. It may be advisable in some cases to sow oats on such ground and when the greatest growth has been attained, plow under the entire crop. Manure, however, has the greatest effect on alkali spots and should be used wherever available in sufficient amounts. In other cases green manures, or straw may serve for the purpose but where such materials are used, a small application of manure should be made along with them in order to hasten the decomposition processes which in turn hasten the removal of the excess of salts. No other fertilizing constituents are of value in reclaiming alkali soils as far as is known. The thoro drainage of the areas and the introduction of an abundance of organic matter are the most effective methods which can be employed.

\*\*Bull. Ia. Agr. Exp. Sta. 177—The alkali soils of Iowa.

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

The needs of Wright county soils have been indicated in the tests in the laboratory, greenhouse and field and hence some general conclusions may be drawn regarding the treatments which should be practiced in the county. The field experiments, while located in other counties, are on soil types which occur in this county and hence the data given may be considered to indicate quite definitely the results which may be expected from the use of the same materials in this county.

The suggestions offered are not only based on the tests discussed earlier but they are based on practical experience and no recommendations are made which are not of proven value. Tests which are suggested may be readily carried out on the farm and indeed are being followed on some farms now with desirable results. It is not possible yet to say positively which phosphorus fertilizer should be employed and farmers are urged to test both rock phosphate and acid phosphate on their farms. Only in this way will it be possible to insure profitable results.

### MANURING

Many of the soils in Wright county are not particularly well supplied with organic matter and additions of fertilizing materials supplying organic matter are very desirable. Some of the types, particularly the Webster silty clay loam, the Webster silt loam and some of the terrace and bottomland soils are black in color and rich in organic matter. But even on these soils organic matter must be supplied at regular intervals or the soils will become deficient in time. The addition of manure on these soils is desirable, and beneficial effects are secured as has been noted in the experimental work referred to earlier. On the lighter colored soils, however, larger effects are secured. Thus the Carrington and Clarion soils respond very profitably to manuring. Larger applications should be made to these types and more care taken to build up the supply. On the Webster soils, small applications may be made, but not just preceding the small grain crop of the rotation, owing to the danger of causing it to lodge. The need on these soils is merely to keep up the supply. There are other effects of farm manure on these richer soils which probably account in part at least for the beneficial influence on crop yields.

Manure benefits crop growth because of its effect on the physical, chemical and bacteriological conditions in soils. It opens up heavy clay soils, making them less impervious, better aerated, better in moisture content, warmer and better suited for the proper production of available plant food. The physical effects of manure on the Webster soils may account in part for its beneficial influence on crop yields. Manure also improves the physical conditions in sandy soils, making them more retentive of moisture, less aerated and less subject to losses by leaching. Chemically manure is of value on soils because it returns to them a large part of the essential plant food constituents removed by the growth of crops. Hence it actually lengthens the "life" of the soil, or prolongs the time until any of the essential plant food constituents become deficient. It

serves therefore to keep up the producing power of the soils. It also adds large amounts of organic matter which affects the soil chemically and physically. This organic matter also has a bacterial effect and the general result is a better production of available plant food. The bacteria present in the soil are stimulated to greater activity by the addition of organic matter. Then too, manure contains enormous numbers of bacteria and when these are added to the soil there is a stimulation in bacterial action which brings about more available plant food production. On rich soils, the bacterial effects of manuring may be the most important, as such types, especially if not well drained may be weak in bacterial action and slow in producing available plant food. Small amounts of manure often prove very desirable on newly drained areas because of the effect in stimulating bacteria to greater action. The bacterial effects of manure may account in part for its value on the Webster soils and the Fargo and Wabash types in this county. In general, however, on most soils, the beneficial effects of manure are due to a combination of chemical, physical and bacterial effects.

Manure is subject to losses, when stored, which may seriously reduce its fertilizing value. When kept in loose piles exposed to the weather, to alternate wetting and drying and to a washing away of the liquid portion, 70 to 90 percent of the valuable constituents of the manure may be lost. When such losses occur the crop increases from the use of manure are much smaller and hence mean actual money losses on the farm.

There is no one method for storing manure to keep the losses down, which can be recommended for use under all conditions. It may be stored in a covered yard, or in a pit. It may be composted. It may merely be kept under cover, or some other method may be employed which is particularly suitable to the individual farm conditions. Whatever method is followed makes little difference provided the manure is kept moist and compact and protected from the weather. Application of manure is sometimes made to soils, as it is produced and when this is possible practically no losses occur and there is no storage problem. In general, however, it is necessary to follow some storage method. Even under the very best conditions of storage some losses occur, but by keeping them as low as possible by some of the methods suggested or by applying the manure as produced it is estimated that as much as 75 percent of the valuable plant food removed from the soil may be returned.

There is very little danger of supplying too much manure to soils, as on the average livestock farm there is an insufficient production to meet the needs of all the soils, using a normal amount. Eight to 10 tons is the usual application, once in a four year rotation. Occasionally larger amounts may be used profitably but generally the smaller applications give greater crop effects per ton of manure than the larger amounts. In no case, however, is it desirable to apply more than 16 to 20 tons per acre to Iowa soils. It is most desirable that some manure be applied regularly to all the soils on the farm and hence large applications, obviously cannot be made to any areas without leaving other parts of the farm untreated. On the dark colored types smaller amounts than the normal 8 to 10 ton applications may be made with profit. Particularly when the soil is newly drained, will a small amount prove desirable to stimulate bacterial action. On such types, manure should never be applied just preceding the small

grain crop, owing to the danger of causing it to lodge. When the manure is applied at some other point in the rotation the most desirable effects will be secured.

The beneficial effects of manure in increasing crop yields have been indicated in the experiments reported earlier. Farm experience confirms the conclusion that manuring is a most important practice and farmers in Wright county should carefully preserve the manure produced and apply it to their land, if they would secure the best yields and keep their soils productive. Manuring is a basic soil treatment and other fertilizers rarely give as large effects unless manure is applied first.

#### GREEN MANURING

In grain farming, there is little production of manure and some other material must be employed to supply organic matter and serve as a basic fertilizer treatment. On many livestock farms, too, the production of manure will not keep all the soils on the farm supplied and some other material must be employed to supplement the manure. In both cases green manures may be employed. Legumes are preferable for use as green manures because of the fact that when well inoculated they use the free nitrogen of the atmosphere. Hence when turned under in the soil, they not only add organic matter, but also nitrogen, serving to keep up the supply of both constituents. Non-legumes may be used as green manures but will not add any nitrogen to the soil. So many legumes are available for use under such a wide variety of soil and climatic conditions that it is rarely desirable to use non-legumes.

Green manuring may be very desirable in some cases in Wright county, when farm manure is not available for use, and when practiced, legumes should be employed and should be well inoculated. The practice should not be followed blindly or carelessly or there may be undesirable effects. A heavy green crop should not be turned under in a dry season or the succeeding crop may be injured because of undesirable moisture conditions. Frequently a part of the legume crop in the rotation serves as a green manure and produces desirable effects. The first crop of clover may be cut and the second plowed under. The effects will depend, of course, upon the actual amount of green material turned under. If the seed only of the legume is removed and the rest of the crop plowed under, there is a large green manuring effect. Advice regarding green manuring under special soil conditions will be given by the Soils Section upon request.

Crop residues serve materially in keeping up the supply of organic matter in soils and they also add some plant food. Hence they are of considerable value and should always be thoroly utilized. Straw and stover should never be burned or otherwise destroyed but they should be turned under in the soil. On the livestock farm they should be used for feed or bedding and returned to the soil in the manure. On the grain farm the straw may be allowed to decompose partially before application, or it may be applied directly to the soil. It is especially desirable to use all crop residues on the grain farm but they should never be wasted on the livestock farm as they are valuable for keeping up the organic matter and plant food supply.

### LIMING

Most of the soils in Wright county are acid in the surface soil but the Webster silty clay loam, the most important upland type usually is not acid but basic in reaction. It often contains considerable lime in the surface as well as in the lower soil layers. The Webster loam is likewise often basic in the surface soil but in some areas it shows acidity at the surface altho there is much lime in the lower soil layers. The Fargo soils on the terraces are generally basic in reaction and may contain much lime even in the surface soil. Occasionally other types in the county may show some lime in the lower soil layers but except for the Clarion loam which typically is high in lime in the subsoil, the presence of lime in these types is not typical and not general and may be considered local and not of wide significance. Except for the Webster and Fargo soils, therefore, the soils of the county are apt to be in need of lime and in some cases the Webster surface soils need lime.

Soils which are acid in reaction will not yield the most satisfactory crops. Legumes such as red clover and alfalfa are especially sensitive to acidity and often refuse to grow in acid soils. But all general farm crops are benefited by additions of lime to acid soils. Corn and small grains are not sensitive to acidity but increased yields are secured when lime is applied probably due to the indirect effects of liming. Even where the surface soil only is acid lime may be of value in making conditions better there for the early growth of the crop. The greenhouse and field results given earlier in this report indicate the value of applying lime to some of the Wright county soils. Farm experience confirms the conclusion that lime should be applied on acid soils if the best crop yields are to be secured.

Liming benefits soils because it improves them physically, chemically and bacteriologically. Light, sandy soils are made less droughty, less subject to losses of moisture and plant food, and more retentive of necessary organic matter. Heavy, tight clays are opened up, better aerated, and better fitted for the production of available plant food. Lime supplies the element calcium which is needed by crops and is sometimes deficient. It improves soils chemically also by neutralizing the acids present or produced, which, if allowed to accumulate reduce the fertility of the soil. All desirable bacterial activities are increased by liming, there is some decomposition of organic matter, more nitrification, more nitrogen fixation and in general a greater production of available plant food. Increases in crop yields from the use of lime may be due to its physical, chemical or bacterial effects but in general they may be attributed to all three and it is impossible to say which is the most important.

The value of lime on acid soils, regardless of the reasons therefor, is so great that applications should be made whenever necessary. Farmers may test their own soils to determine the lime requirement but it will be more satisfactory if they will send in a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. In this way they may be sure of applying the proper amount. Too small applications will not have as large effects and too large applications will prove too expensive and very undesirable. The lime requirement of soils is extremely variable and applications of lime should be made only after tests have shown how much to use. Variations

may occur in the same soil type in different fields. Hence samples from every field should be tested. The data given earlier in this report should be considered merely to indicate the needs of the various soil types and should not form the bases for applications. The farmers in Wright county should have their soils tested to determine lime needs and should then apply whatever lime is necessary. One test and one application of lime will not suffice for all time. Lime disappears gradually from soils by leaching and in other ways and hence soils need to be tested at regular intervals if the supply of lime is to be maintained. It is suggested that the tests be made preceding the legume crop of the rotation and the lime may then be applied when it will produce the most effect.

Liming is an important practice in Wright county, not only for securing the best crop yields but also for keeping the soils permanently productive. The testing of soils and the use of lime in proper amounts is an important farm practice. Further information regarding liming, losses from the soil, crop effects and other points in connection with the process is given in Bulletin 151 and Circular 105 of the Iowa Agricultural Experiment Station.

#### **THE USE OF COMMERCIAL FERTILIZERS**

The supply of phosphorus is low in most of the soils of Wright county and phosphorus fertilizers will be needed in the future if crops are to be properly supplied. But results may be secured from their use at the present time, in some cases, for where the total content of phosphorus is low, there is very apt to be a very slow production of available phosphates. Even where there is apparently a good supply, available phosphorus may be lacking and phosphorus fertilizers will give results. As the amount of phosphorus in soils decreases, however the production of available phosphorus decreases more rapidly. Hence many of the soils of Wright county might be expected to respond to phosphorus fertilization now. The greenhouse and field tests reported on earlier indicate that phosphorus may often be profitably applied to the soils in this county, to the richer types as well as to the poorer soils. The total phosphorus content of the soils merely indicates their needs and the only way to tell whether or not phosphorus fertilizers should be used is to test the value of an application to a small area. The results secured experimentally while not conclusive do indicate the great desirability of testing phosphorus carriers on Wright county soils.

There are two phosphorus fertilizers which may be employed, rock phosphate and acid phosphate. Acid phosphate provides the element in an available, readily utilizable form while the phosphorus in rock phosphate must be made available after application to the soil. Acid phosphate costs more than the rock but it is used in smaller amounts, usually being applied at the rate of 200 pounds per acre annually. Rock phosphate is cheaper but it is used at the rate of 2,000 pounds per acre once in a four-year rotation. It does however supply more total phosphorus. The field tests now under way include both materials and later it may be possible to choose that one which will give the greatest effects and the most profitable returns. For the present definite conclusions cannot be drawn. The results given earlier in this report indicate that acid phosphate may sometimes prove the most desirable but in other cases rock phosphate may be preferable. The effects of the two materials are different under

different soil and crop conditions. It is urged, now, that farmers test both materials on their own soils and thus they may learn whether or not phosphorus is necessary on their particular soil and whether the rock or the acid phosphate should be employed. It is a simple matter to make such tests on the farm and directions which may be readily followed are given in Circular 82 of the Iowa Agricultural Experiment Station.

There is considerable nitrogen present in some of the soils in Wright county but in other cases the supply is not so large and it is necessary that some materials be employed in keeping up the content. Nitrogen disappears constantly from soils, thru assimilation by plants and washing away in the drainage water. Hence nitrogen must be considered in all cases in planning systems of permanent fertility. Fertilizing materials supplying nitrogen must be employed to make up for the losses and in some cases should be used to build up the supply.

Farm manure may return to the soil much of the nitrogen removed by the crops grown and hence it serves as a most important means of keeping up the nitrogen supply in soils. But the grain farmer must use something else for this purpose and often the livestock farmer must supplement the farm manure application. Leguminous crops used as green manures make the cheapest and best nitrogenous fertilizer for they supply both nitrogen and organic matter. If the legume is well inoculated, as it should be, the free nitrogen of the atmosphere is fixed in the crop in considerable amounts and when it is turned under in the soil there will be an increase in nitrogen depending, in amount, upon the amount of the crop. If only a part of the legume is plowed under, there will be only a partial fertilization with nitrogen. If the nitrogen content of soils is to be built up and kept up the major part of the legume in the rotation must be plowed under or some legume must be used as a "catch" crop, seeded in the corn at the last cultivation or as a cover crop. Crop residues, when properly turned under in the soil also aid in keeping up the supply of nitrogen.

Commercial nitrogenous fertilizers are not recommended for general farm crops grown in this county. They may possibly be used in small amounts as top dressings but by the proper use of farm manure, crop residues and leguminous green manures, it is possible to increase and maintain the nitrogen in soils at a low cost. There is no objection to the use of commercial nitrogen but tests should be carried out on small areas before an application is made to a large acreage for it is not believed that Wright county soils will respond profitably, to their use at the present time.

Analyses have shown a very large content of potassium in the soils of the state and it would not be expected that potassium fertilizers would be desirable for general use. If soils are kept in good physical condition, with abundance of organic matter, there should be a sufficiently rapid production of available potassium to keep crops supplied. There may be cases however where there is not enough available potassium and when this is true a soluble potassium fertilizer might prove of value. Their general use cannot be recommended and they should only be applied after tests on small areas have shown their value. Small amounts used as top dressings to stimulate early growth may be desirable in some cases and small applications to newly drained areas may prove profitable

but with proper care of the soils, it does not seem likely that potassium fertilizers should be needed in this county.

Complete commercial fertilizers containing nitrogen, phosphorus and potassium are probably unnecessary for use in Wright county at the present time. Nitrogen may be more cheaply supplied in leguminous green manures and potassium is not likely to be needed. Phosphorus may be more cheaply supplied in acid phosphate and from the experiments reported earlier, it would seem that the phosphates will give more profitable returns than the complete materials. The latter are much more expensive and hence very much larger crop increases must be secured from their use if they are to prove more profitable than phosphates. It is possible that complete brands may be used in some cases with desirable results but only by tests on small areas, comparing the results with those secured from acid phosphate can their value be definitely determined. There is no objection to the use of the complete brands if they are shown to be profitable. Farmers may test these materials along with phosphates if they wish and they can thus determine the desirability of using them on their own soils. In general it is believed the phosphates will prove quite as profitable on Wright county soils, if not more so.

### **DRAINAGE**

The need of drainage in Wright county has been emphasized in a previous section of this report. Attention has been called to the fact that there is much land in the county which has no adequate natural drainage. Drainage ditches have been installed, natural drainage channels have been deepened and made more effective and much tile has been installed. Hence the drainage conditions in the county have been much improved. But there are still areas which would be improved by drainage. The Webster silty clay loam, the Fargo silty clay loam, the Bremer silt loam and the Wabash soils on the bottoms are all productive when properly drained. If drainage is poor however crop yields are low. There are other types which need drainage in some areas and when this is true the yields of crops will not be satisfactory.

Drainage is a fundamental soil treatment and other methods of treatment will be of little value on soils which are too wet. The tiling out of many areas may be desirable still in Wright county and if the tiling has not been adequate, more should be installed. The cost of tiling may be considerable but it is well warranted by the effects on crop growth which result. In planning for the most profitable system of soil management and for permanent fertility, drainage should be considered of basic importance.

### **THE ROTATION OF CROPS**

Growing one crop continuously on a soil will very quickly reduce its fertility. It is very important therefore that some rotation of crops be adopted for all soil conditions. The large money value from some crop often leads farmers to grow that crop continuously with the idea of securing the greatest returns from the land. It has been shown, however, that continuous cropping reduces yields so rapidly that greater money returns are secured over a period of years, where a rotation is practiced, in spite of the inclusion in the rotation of crops which



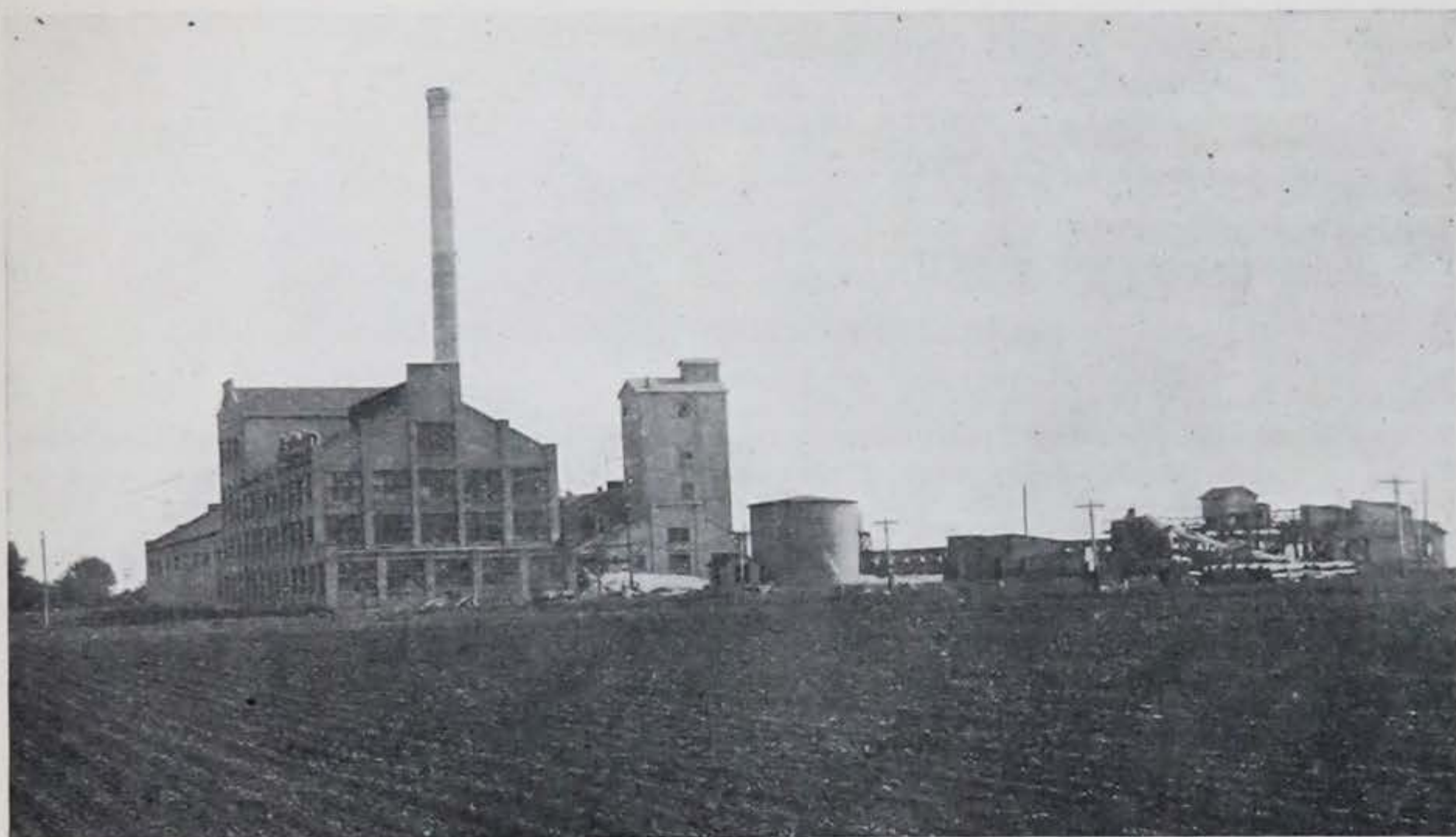


Fig. 7. Beet sugar factory at Belmond. Beet growing is practiced quite extensively in the county.

are of less value. This is due to the fact that under the rotation system yields are not reduced so rapidly.

In Wright county, some desirable crop rotation should always be used, if the most satisfactory crop yields are to be secured continuously and the soils kept highly productive. No special studies on rotations for this county have been conducted but several are suggested which are in use in the state and may prove satisfactory. Almost any rotation may be employed provided it contains a legume and the money crop. The following are typical rotations:

#### 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.

#### 2. FOUR OR FIVE-YEAR ROTATION

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

#### 3. FOUR-YEAR ROTATION WITH ALFALFA

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

#### 4. FOUR-YEAR ROTATIONS

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

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

#### 5. THREE-YEAR ROTATIONS

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

### THE PREVENTION OF EROSION

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

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will of course wash over it and much of the soil may be carried away in this manner to the detriment of the land.

Light, open soils which absorb water readily are not apt to be subject to erosion while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles

together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance but it is less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient.

In Wright county erosion occurs to some extent in the Carrington loam, the Clarion loam, and in the sandy Carrington types. Little washing has occurred on the terraces except on the older, higher areas. Erosion is not a serious problem in this county but wherever washing does occur the soil should be protected. It is important therefore to consider the means which may be employed to protect the rolling areas from injury by washing away of the surface soil.

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

#### EROSION DUE TO DEAD FURROWS

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

*"Plowing In."* It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas where the soil is deep, this "plowing in" process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

*"Staking In."* The method of "staking in" is better as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point up-stream. Additional brush may also be placed above the stakes, with the tops pointing up-stream, 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. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

## SMALL GULLIES

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

*Checking Overfalls.* The formation of small gullies or ditches is practically always the result of overfalls and one of the most important problem is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is very desirable before any success can be had in filling small or large gullies.

*"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 stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward, is left near the top. This heavy branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away as readily by the action of a large volume of water. A series of these brush-piles may be installed up the course of the gully and with the regular repair of washouts or undercuttings may prove very effective.

The modification of this system of "staking in" which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of four to 10 feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed upstream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend of course upon the size of the gully. These posts should be set well into the ground and spaced about four feet apart, being arranged in a V-shape with the point downstream and lower in the center than at the sides of the ditch. This modification of the "staking in" method is proving very satisfactory.

*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 pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving of time, labor and inspection.

*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. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

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

*The Adams Dam.* This dam is practically the same as the Christopher or Dickey Dam. In fact the principle of construction is identical. In some sections the name "Adams dam" has been applied and hence it is mentioned separately. This is one of the most satisfactory methods of filling gullies and the dam may also serve as a bridge. The installation of a culvert is generally made of sewer tile with tightly cemented joints and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an up-stream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially the larger gullies.

*The Stone or Rubble Dam.* Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making such dams the results in small gullies may be quite satisfactory, especially when openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

*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 re-

sults are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

*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. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

*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. The amount of land lost from cultivation in this way is relatively small as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and it might be employed to advantage in many other cases.

*The Concrete Dam.* One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. 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. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

#### LARGE GULLIES

The erosion in large gullies which are often called ravines may in general be controlled by the same methods as in the case of small gullies. The Christopher or Adams dam, already described, is especially applicable in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

## BOTTOMLANDS

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

*Straightening and tiling.* The straightening of the larger streams in bottomland areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and it often proves very efficient.

*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. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

## HILLSIDE EROSION

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

*Use of Organic Matter.* Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green

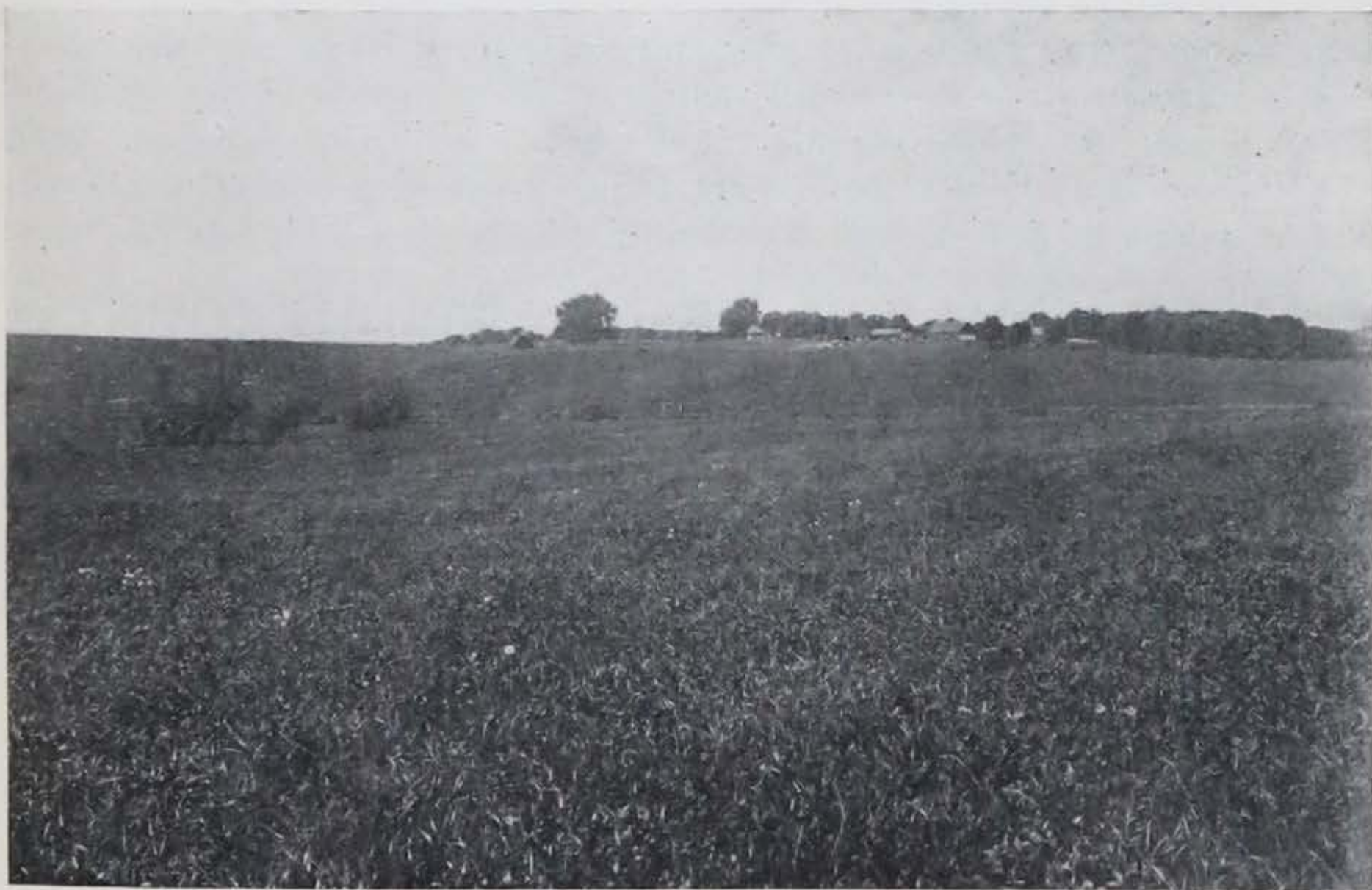


Fig. 8. Gently rolling topography of the Carrington loam.

manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw and corn stalks may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

*Growing Crops.* The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also quite desirable for use in such locations. The root system of such crops as these holds the soil together and the washing action of rainfall is reduced to a marked extent.

*Contour Discing.* Discing around a hill instead of up and down the slopes or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proven quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

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

*Deep Plowing.* Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation as too much subsoil may be mixed with the surface soil and the productive power of the soil therefore, reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

## INDIVIDUAL SOIL TYPES IN WRIGHT COUNTY\*

The soils in the county are grouped into three classes according to their origin and location. These are drift soils, terrace soils and swamp and bottom-land soils.

### DRIFT SOILS

There are six drift soils in the county, classified in the Webster, Carrington and Clarion series. Together they cover 92.5 percent of the total area.

#### WEBSTER SILTY CLAY LOAM (107)

The Webster silty clay loam is the most extensive soil type in the county, covering 29.5 percent of the total area. It occurs in all parts of the county, lying in depressed areas between streams, where swampy conditions formerly occurred. It also occupies undrained sloughs and flat areas between the hills

\*The descriptions given in this section of the report very closely follow those in the Bureau of Soils Report.



in the morainic area in the eastern part of the county. It is found mainly in small individual areas either associated with the Webster loam or with the Carrington and Clarion loams. The largest single area occurs in Woolstock township, extending from the county line east of the town of Woolstock, north for 8 miles in an irregular shaped area, well into Dayton township. Another rather extensive area occurs south of Wall lake and a third area larger than typical is found in Lake township.

The surface soil to a depth of 12 to 24 inches is a black, sticky silty clay loam. The upper subsoil is a tough clay loam, dark brown or mottled gray and brown in color, usually a few inches in thickness. The lower subsoil is a clay loam, gray in color or gray mottled with yellow or brown. When light in color, the subsoil is friable and contains much white silty floury material. It is a whitish-gray in color when dry and is either granular or chalky. In places the subsoil is a heavy mottled or olive gray clay. In the lower areas the black soil extends deeper, often thru the three-foot section. Small areas of peat and muck, too small to show on the map, are included with the type. In some of the low areas the texture is heavier and approaches a clay. These areas are too small to show on the map. They are known locally as "gumbo". In the morainic region, the depth of the surface soil and subsurface layer is variable, ranging from 15 inches to three or four feet. In some of the areas in this section, the subsoil below 30 inches consists of layers of coarse, gravelly material, grayish in color. In the area extending thru Dayton and Woolstock townships between Eagle creek and White Fox creek, the surface soil is much lighter in texture than the typical soil, containing considerable silt and sand. The subsoil of the type always contains considerable amounts of lime and in places there is lime in the surface soil. As a rule, however, the lime is not abundant above 20 inches. In narrow strips along the edge of peat and muck areas, and near former ponded areas, there are heavy accumulations of lime forming what are known as "alkali" spots. These spots are of local occurrence and in-extensive.

In topography the Webster silty clay loam is flat to depressed. It is naturally very poorly drained. Much of it has been drained and brought under cultivation by the installation of drainage ditches 8 to 15 feet in depth and the laying of tile.

The greater part of the type is under cultivation, but there is a considerable area, yet undrained, which is used for hay or pasture. General farm crops are grown on the cultivated portion. Corn yields vary from 25 to 70 bushels per acre, depending largely on the seasonal conditions. Oats yield from 25 to 50 bushels and hay from 1 to 2½ tons per acre. Sugar beets are grown in some areas, yielding from 10 to 15 tons per acre.

When well drained, crop yields are usually excellent on this type. It must be thoroughly drained, however, before good crop yields can be secured. It should be cultivated carefully to keep a good physical condition. It should not be plowed when wet or it may clod. In dry seasons, if uncultivated, the surface soil will dry and crack. Fall plowing is very desirable. Small amounts of farm manure will be of value on the soil, improving the physical condition, and this material will be very effective on newly drained areas, as it stimu-



Fig. 9. Level stretches of Webster loam occur over considerable areas.

lates bacterial action and the production of available plant food. Manure should not be applied on this type just preceding the small grain crop owing to the danger of causing it to lodge. Liming is usually unnecessary, but when the surface soil is acid a small amount may help to start legume growth. Phosphorus fertilizers may prove profitable on some areas and tests are very desirable. On the so-called "alkali" spots, drainage is needed first and heavy applications of manure, or the turning under of a green crop will hasten the removal of the excess of lime.

#### WEBSTER LOAM (55)

The Webster loam is the second largest type in the county, covering 25.1 percent of the total area. It occurs extensively in the western half of the county. It is also found in the southeast central part, around Wall lake. Small areas occur throughout the morainic region, bordering poorly drained level areas or ponded spots. In the western part of the county, it is associated with the Webster silty clay loam mainly. It also adjoins areas of Clarion loam. There are no extensive areas of the Webster loam, however, which are not cut by the flat or depressed areas of the silty clay loam.

The surface soil of the Webster loam is a black friable heavy loam, extending from 10 to 16 inches in depth. The subsoil to 20 to 22 inches is a very dark brown to black plastic loam. Below it is a yellowish-brown, crumbly silty clay loam, mottled with yellow and olive-gray. It is heavy and plastic, but at the lower depths contains much coarse sand and some pebbles. Below the 3-foot section there is a yellowish-brown to gray mottled clay loam. In the flatter areas the surface soil contains much silt and clay and approaches a silty clay loam in texture. In some areas where there are low mounds there is much coarse material both in the surface soil and in the subsoil. There is a gradual change from the Webster loam into the silty clay loam and hence the boundary lines between the types are often drawn arbitrarily. The subsoil of the type

is high in lime, but the surface soil only infrequently contains any lime. It is usually slightly acid in reaction.

In topography, the Webster loam is level to flat. Natural drainage is poor and only in the low mounds is there not a need for drainage. Much of the land has been drained thru the laying of tile and the installation of drainage ditches.

Most of the type is cultivated and general farm crops or tame grasses are grown. Only in the northeastern and northwestern parts of the county on some poorly drained areas is there any growth of native prairie grasses. Corn is grown most extensively and yields 40 to 80 bushels per acre, averaging about 50 bushels. Oats yield from 40 to 75 bushels and timothy and clover  $1\frac{1}{4}$  to  $1\frac{1}{2}$  tons per acre. Alfalfa yields from 3 to  $3\frac{1}{2}$  tons. Sugar beets are grown to some extent and yield 12 tons per acre on the average.

Crop yields are generally quite satisfactory on this type when it is well drained. Drainage, however, is the first treatment needed. Applications of farm manure prove of value and are particularly desirable on newly drained areas. Liming is necessary when the surface soil is acid, in order to give legumes a good start. Phosphorus fertilizers will probably prove of value and tests on small areas with acid phosphate and rock phosphate are very desirable. Tests in the field have indicated that the soil may respond to phosphorus.

#### CARRINGTON LOAM (1)

The Carrington loam is the third largest type in the county, covering 22.1 percent of the total area. It occurs most extensively in the eastern part of the county, in the morainic region, being associated with the Webster loam and the Clarion loam. It is found also in the extreme western part of the county associated with the same types and also with the Webster silty clay loam. There are no large continuous areas of the type. It is everywhere cut by small areas of the Webster silty clay loam, spots of Clarion loam and small areas of Webster loam, Carrington fine sandy loam, peat and other minor types.

The surface soil of the Carrington loam is a dark-brown, mellow friable loam, 12 to 16 inches in depth. The subsoil is a yellowish-brown silty clay loam to clay loam, mottled with gray and yellow in the lower depths. Coarse sand and some pebbles occur in the subsoil. In some areas the subsoil at 28 to 30 inches is a gritty coarse clay loam. In the morainic region in the eastern part of the county, the surface soil is lighter in color and shallower, containing also more fine sand. There are outcrops of calcareous sand and gravel on the tops of ridges and knolls in the type in this section. Narrow draws and small depressions where the soil is a heavy silty clay loam are included in the type as they are too small to separate out. In the southwestern part of the county, along the steeper slopes of the Boone river, there are areas where the surface soil has been washed away and the yellowish-brown, gritty clay of the subsoil is exposed. In Troy township, along the east bank of the Boone river, one mile northwest of Woolstock, the soil is a whitish-gray silt loam at the surface, passing into a tenacious grayish-brown subsoil, containing many yellow mottlings and very impervious. These areas are small, flat and scattered, totaling about 25 acres. They are included with the Carrington loam because of their small

extent. In Belmond township, on some of the small areas on gentle slopes, the surface soil contains more silt and the texture approaches a silt loam.

The Carrington loam is gently rolling in topography over much of the area, varying to steeply rolling to rough in the morainic region and along the Boone river in the southwestern part of the county. Drainage is generally entirely adequate, only on a few of the broad flat tops of areas between streams is there need for drainage. Some erosion has occurred, but erosion is not extensive except in the western part of the county where the surface soil has washed badly.

Nearly all of the type is under cultivation. The rougher, more rolling areas near the streams are in grass. Wooded areas occur only in narrow strips on slopes to the streams. Some of the steep eroded hillsides along the Boone river are wooded and support a natural growth of bluegrass. General farm crops are grown on the cultivated areas. Wheat yields 15 to 30 bushels per acre, averaging about 20 bushels. Spring wheat is grown almost exclusively. Yields of corn and oats are about the same as those secured on the Webster types. Hay crops yield well.

The Carrington loam is naturally a productive soil, but crop yields may be increased by proper treatment. Applications of farm manure are very desirable and bring about large increases in crops. Experiments and much farm experience have shown the value from the use of farm manure. Liming is needed when the soil is acid in order to secure the best legume growth. Phosphorus fertilizers may be very desirable on this type. Experiments have shown that phosphorus carriers may give profitable crop increases and it is very desirable that farmers test the value of both rock phosphate and acid phosphate on their own soils, to determine the need of phosphorus and which material will give the best results.

#### CLARION LOAM (138)

The Clarion loam is the fourth largest type in the county, covering 13.9 per cent of the total area. It occurs in all parts of the county in many small areas in association with the Webster and Carrington soils. There are no extensive individual areas, all are cut by areas of the Webster silty clay loam or other types. The areas of the type are larger and more numerous on the gentle slopes toward the streams.

The surface soil of the Clarion loam varies somewhat, depending upon the conditions under which it occurs. In low or nearly flat areas, it is a black loam, 12 to 20 inches in depth, underlain by a gray, highly calcareous subsoil. On the higher, gently rolling areas, the surface soil is dark brown in color, and 6 to 12 inches in depth. The upper subsoil is a dark brown clay loam grading into a brown, more friable clay loam. At 20 to 30 inches it becomes a light brown, yellowish-brown, or grayish-yellow friable clay loam or silty clay loam. Small quantities of coarse sand, pebbles and boulders occur throughout the soil and subsoil. There are narrow strips on the tops of ridges and on steep hill slopes where the dark-colored surface soil has been removed and the light-colored calcareous till is exposed. Near the surface in such areas pockets or beds of sand and gravel occur.

In topography, the Clarion loam is undulating to strongly rolling or rough.

Drainage is good in practically all cases. There are very few areas where artificial drainage is needed. Erosion has occurred to some extent in the rougher areas and on some steep slopes the surface soil has been very largely removed.

Practically all of the Clarion loam is cultivated and general farm crops are grown. Corn is the principal crop and yields very much the same as on the Carrington loam. Oats and clover give about the same yields as on the Carrington loam. Clover is grown less frequently, however.

Crop yields are quite satisfactory on the Clarion loam, but larger crops may be secured thru manuring, liming and applying phosphorus fertilizers. Farm manure has been shown by experiments and farm experience to bring about large effects on crops. Liming is often necessary as the surface soil of the type is apt to be acid. The subsoil is usually well supplied with lime. There are indications from field experiments that phosphorus fertilizers will prove valuable and tests of rock phosphate and acid phosphate on the farm are very desirable.

#### CARRINGTON SANDY LOAM (3)

The Carrington sandy loam is a minor type in the county, covering 1.0 percent of the total area. It occurs practically all in the southeastern corner of the county in Blaine and Vernon townships. It is found mainly on an extended chain of hills, somewhat over six miles in length. Other small areas occur on ridges and knolls in this part of the county and smaller areas are scattered throughout the county, many too small to show on the map.

The surface soil of the Carrington sandy loam is a brown to dark brown sandy loam, extending to a depth of 10 inches. The subsoil is a coarse, yellowish-brown sandy loam, having a grayish cast. Much coarse sand and gravel occurs in the surface soil and subsoil. On the gentle slopes, the color of the soil is darker and it is more loamy in texture. On the tops and sides of knobs and ridges, it is usually a sandy to fine sandy loam underlain by a loose calcareous, gravelly till. Two miles northwest of Dows there is a hill called a "kame" which is included with the type. It is a gravelly surface soil, underlain at a depth of 15 to 18 inches by a coarse calcareous gravel.

Most of the type is cultivated and general farm crops are grown. Average crop yields are somewhat less than on the Carrington loam. Clover and forage crops do well and should be grown more generally in order to build up the organic matter supply. The type is rolling in topography and subject to drought. Additions of organic matter are very necessary in order to protect the soil from drying out so rapidly. Farm manure should be used in liberal amounts and leguminous crops should be used as green manures, at least as partial green manures, by turning under the major portion of the crops. The type is acid in some cases and when this is true, liming is necessary. Phosphorus fertilizers will probably be of value in this soil and tests are very desirable.

#### CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor type in the county, covering 0.9 percent of the total area. It occurs on hills and ridges north and east of Elm and Cornelia lakes and on the higher hills along the Iowa river from a point

five miles south of Belmond to where the stream leaves the county, about one mile north of Dows. It also occurs in small strips and scattered areas north and northeast of Rowan.

The surface soil of the type is a brown to dark-brown fine sandy loam, extending to a depth of 18 to 20 inches. At that point it grades into a light yellowish-brown fine sandy loam, becoming coarser at the lower depths. Gravel and small boulders occur thruout the surface soil and the subsoil. Outcrops of gravelly material occur on the steeper slopes.

The type is rough in topography and droughty. General farm crops are grown, but yields are lower than on the other Carrington types. The soil needs particularly liberal applications of farm manure and leguminous crops as green manures in order to build up the organic matter supply and make the soil more productive. It is generally acid and needs lime, especially for legumes. It would probably respond also to phosphorus fertilizers and tests are recommended. The growing of legume crops is particularly desirable in order to increase the content of organic matter and nitrogen.

### TERRACE SOILS

There are six terrace soils in the county, classified in the O'Neill, Buckner, Fargo, Waukesha and Bremer series. They are all small in area, together, covering only 3.5 percent of the total area of the county.

#### O'NEILL LOAM (108)

The O'Neill loam is the largest of the terrace types, covering 1.2 percent of the county. Practically all of it occurs along the Iowa river and West Branch, in a continuous body seven miles long and about one and one-half miles wide. The town of Belmond is located on the type almost in the center of the area. Several small areas occur along the Boone river south of Eagle Grove and to the east along Eagle creek.

The surface soil of the O'Neill loam is a dark-brown friable loam, about 12 inches in depth. The subsoil is a lighter brown sandy loam to fine sandy loam to about 28 inches, where it passes into a brown to reddish-brown fine sandy loam, containing much coarse material and pebbles. At a depth of 30 to 40 inches gravel and sand are found in layers of varying thickness. Some gravel occurs in the surface soil in most areas.

In topography the O'Neill loam is level, lying on a terrace 10 to 15 feet above overflow. North of Belmond, the terrace is somewhat older and higher and for a distance of about 2½ miles is 15 to 20 feet above overflow. On this higher area, the soil is only 12 to 15 inches deep and underlain by coarse gravel. Several commercial gravel pits are in operation. The type is well drained and in dry seasons is droughty.

The type is all under cultivation except the town site of Belmond, and about 150 to 200 acres from which the surface covering has been stripped to allow for the removal of the gravel. Corn yields 25 to 45 bushels per acre in good seasons and oats from 25 to 40 bushels. Timothy and clover do well. Potatoes and truck crops are sometimes grown and give good yields.

The O'Neill loam needs organic matter and should receive liberal applications of farm manure, or legumes should be turned under as green manures.



Fig. 10. Typical rolling topography.

It is acid and in need of lime. Phosphorus fertilizers would probably prove of value and tests of rock phosphate and acid phosphate are recommended. Large additions of organic matter will be of special value on the type to permit of the retention of moisture. When truck crops are grown, special brands of complete commercial fertilizers may be of value.

#### BUCKNER LOAM (38)

The Buckner loam is the second largest terrace soil, covering 1.2 percent of the county. It occurs along the Iowa river and the Boone river, mainly in small, narrow, irregular-shaped areas. The areas are found along the Boone river, beginning west of Eagle Grove and extending north. Along the Iowa river the areas extend from the north to a point about six miles south of Belmond. Other areas are found in the southeastern corner of the county along this river. Two small areas occur along Eagle creek, west of Woolstock and four miles north. One large area is found along the Iowa river, starting about 2½ miles south of Belmond and extending for a distance of over three miles.

The surface soil of the type is a brown to dark brown loam extending to a depth of 10 to 14 inches, where it passes into a yellowish-brown sandy loam to fine sandy loam. Some coarse sand and gravel occur throughout the soil section. At depths of 4 to 6 feet gravel beds occur. Pockets of gravel are found occasionally in depressed areas, within the three-foot section. About five miles south of Belmond there are several small areas where the soil is a brown sandy loam to loam, to a depth of 10 to 14 inches, grading into a yellowish-brown fine sandy loam with much coarse sand and some gravel in the lower subsoil.

The type is level in topography, with a gentle incline toward the streams. It occurs on two levels, one 10 feet and the other 15 to 25 feet above overflow. It is all well drained.

The Buckner loam is practically all under cultivation, general farm crops

being grown. Corn yields 30 to 50 bushels per acre in normal seasons. The soil is in need of organic matter mainly and will respond to liberal applications of farm manure. Legumes should be used as green manures to build up the content of organic matter and nitrogen. Lime is needed to remedy acidity and phosphorus fertilizers would probably prove of value.

#### FARGO SILTY CLAY LOAM (109)

The Fargo silty clay loam is the third largest terrace soil, covering 0.5 percent of the total area of the county. It occurs in numerous areas along the Iowa river, most of them narrow and small. The largest area, about 200 acres, is found on a small creek  $2\frac{1}{2}$  miles southwest of the point where the Iowa river flows out of the county. Small areas occur along the Boone river, west and south of Eagle Grove and in the northwestern corner of the county.

The surface soil of the type is a black tenacious silty clay to clay loam 6 to 8 inches in depth. The upper subsoil is a black clay loam, containing gray mottlings. Below 22 inches the subsoil is a grayish-brown to yellowish-brown clay loam, appearing grayish when dry. In some areas the black soil extends throughout the three-foot soil section. The surface soil varies somewhat in texture, in some places containing some sand and gravel. The subsoil is highly calcareous, containing numerous lime nodules. The surface is usually basic in reaction and often contains much lime.

Much of the type is cropped, but some of the areas are still undrained. Drainage is the first treatment needed and crop yields are usually quite satisfactory when the soil is not too wet. Small applications of farm manure would be of value when the type is newly drained. Phosphorus fertilizers might be of value in some cases.

#### WAUKESHA LOAM (60)

The Waukesha loam is a minor type in the county, covering 0.3 percent of the total area. It occurs in several areas in the southwestern corner of the county along the Boone river, the largest being found just north of the county line.

The surface soil is a brown to dark brown, light-textured loam, 14 inches in depth. The subsoil is a sandy clay loam, yellowish-brown when moist and reddish-brown when dry. Some coarse sand and gravel is found thru the soil section. The lower subsoil is usually a gravelly loam to clay loam. The soil is level in topography and drainage is good. It lies above overflow.

All the type is under cultivation and general farm crops are grown. The yields are about the same as those secured on the Carrington loam on the upland. The soil will be benefitted by applications of farm manure. Leguminous crops should be used as green manure to supplement the farm manure. The type is acid and needs lime. It would probably respond also to phosphorus fertilizers.

#### BREMER SILT LOAM (88)

The Bremer silt loam is a minor type in the county, covering 0.2 percent of the total area. It occurs on the terraces along the Iowa river, one mile south and  $1\frac{3}{4}$  miles north of Belmond. The largest area is a strip 2 miles long and one-half mile wide along a small creek south of Dows.



The surface soil of the type is a dark-brown to black friable silt loam, extending to a depth of 14 inches. The upper subsoil is a brown to dark-brown plastic clay loam, mottled with gray. Below 26 inches it is a yellowish-brown clay loam, mottled with gray and yellow. There is some gravel and pebbles in the subsoil. The surface soil contains more sand in some areas and approaches a loam.

The type is all under cultivation and general farm crops are grown. Yields are usually good, averaging about the same as on the uplands. The type needs drainage and crop yields are low on poorly drained areas. It will respond to applications of farm manure. It is acid and needs lime and it would probably be benefitted by additions of phosphorus fertilizers.

#### FARGO LOAM (17)

The Fargo loam is the smallest of the terrace types, covering 0.1 percent of the total area of the county. It occurs along the Boone river, in the northwestern corner of the county in two areas. Smaller areas are found in the southeastern corner of the county, just east of the point where the Iowa river leaves the county, along White Fox creek, just at the south county line and along the Boone river where it enters the county, two miles west of Woolstock.

The surface soil of the type is a dark-brown to black loam, 10 inches in depth. The upper subsoil is a dark-brown clay loam to clay, mottled with gray and yellow. Below 28 inches, it is a grayish-brown or yellowish-brown clay loam to clay highly mottled with gray. Coarse sand and gravel occur in the surface soil and subsoil. The subsoil is highly calcareous and the surface soil is also usually high in lime. The area mapped along the Boone river southwest of Woolstock is really Fargo very fine sandy loam, but it is included with the loam because of its small extent. It is a dark brown, mellow, very fine sandy loam, 18 inches in depth. The subsoil is a dull-brown to dark brown silty clay loam, and is not calcareous. This area is well drained, while the typical Fargo loam is poorly drained.

The type is mainly under cultivation and general farm crops give fair yields. When well drained yields are about the same as those secured on the uplands. Drainage is the first treatment needed. Small amounts of farm manure will be of value on newly drained areas and will increase crops generally. Phosphorus fertilizers may prove profitable in some cases.

### SWAMP AND BOTTOMLAND SOILS

There are two swamp and bottomland soils classified in the Wabash series and areas of peat and muck, making a total of four soil areas. The total area of bottomland, including a small area of gravel pits (192 acres), makes up 4.0 percent of the county.

#### WABASH LOAM (49)

The Wabash loam is the largest bottomland soil, covering 1.9 percent of the total area of the county. It occurs in narrow strips along the Iowa river, the Boone river, West Branch of the Iowa river, Otter, Eagle and White Fox creeks.

The surface soil of the type is a dark brown to black, friable loam, ranging from 15 to 20 inches in depth. The subsoil is heavier, being a dark brown silty

clay loam containing some fine and coarse sand. The soil is extremely variable owing to frequent overflow. Small scattered areas of fine sandy loam occur, usually containing some coarse material. Areas of silty clay loam are also included with the type, owing to their small extent.

The soil is cultivated only in a few areas, most of it being used for pasture. Trees occur along the streams, scattered over the type. It is subject to annual overflow and if cultivated needs protection from flooding. It would respond to manure, lime and phosphorus if brought under cultivation.

#### MUCK (21 a)

Muck occurs inextensively in the county, covering a total of 2,944 acres or 0.8 percent of the county. It is found in small areas scattered over the entire county. It occupies low, formerly ponded areas and undrained sloughs, and in many of them water stands during the entire year. Marsh symbols indicate where the muck is under water most of the time.

The surface soil of muck is similar to peat except that it is in a more advanced stage of decomposition and it is black in color, loose and fluffy. Some mineral matter, silt and clay, is mixed with the muck around the edges. On some spots there is a covering of 2 to 3 inches of peat. The subsoil below 18 to 20 inches is a black, sticky clay loam to clay, passing at 34 to 40 inches into a dull grayish clay loam to clay. Pockets of sand sometimes occur. The subsoil material is highly calcareous and the surface muck is also apt to be high in lime. The boundary lines between muck and peat are often quite arbitrary.

Many of the muck areas have been drained and are under cultivation. The poorly drained areas support a growth of water-loving grasses, cane and rushes. Sugar beets are grown on some areas. Timothy and clover yield well. Onions, celery and other truck crops grow well on muck. Corn will produce good crops after the muck has been drained and under cultivation for several years. The discussion given earlier in this report, of the needs and treatment of peat soils, applies equally well to muck. Muck may be reclaimed and made productive, however, much more readily than peat and after drainage, will become productive in a few years.

#### PEAT (21)

Peat occurs in the county on an area of 2,432 acres, amounting to 0.7 percent of the total area. It occurs in numerous small areas in all parts of the county, ranging in size from one to several hundred acres. The two largest areas are 1½ miles west of Dows and one-half mile east of Wall lake. There are patches too small to map in depressions in the low-lying flat soils and in draws.

Peat has been described in an earlier section of the report and it occurs typically in this county. As a rule it does not exceed 20 to 24 inches. In a few of the large areas, the depth is greater in the center of the areas, sometimes being four or five feet deep. In many of the smaller areas the depth is only 6 to 14 inches.

Most of the peat in the county has been drained, many areas only for a short time, however. The way in which peat should be handled, the crops which should be grown and other general information regarding peat soils,

are discussed in the section on Peat Soils, and the conclusions reached and recommendations made, apply to the peat in Wright county and need not be repeated here.

#### WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is a minor type in the county, covering 0.5 per cent of the total area. It occurs in narrow areas along the Iowa river, West Branch of the Iowa river, White Fox creek and Otter creek. The most extensive development is along the Iowa river west of Rowan.

The surface soil of the type is a dark brown to black heavy, silty clay loam, 8 inches in depth, having a faint grayish cast. The subsoil is a dark brown, tenacious clay loam to clay mottled with gray. Along Otter creek calcareous material occurs in the three-foot section.

The type occurs in draws and depressions throughout the Wabash loam areas. It is overflowed regularly and is under water in the spring. The soil is utilized mainly for pasture, wild hay being cut from a portion. If cultivated, the type would need first drainage and protection from overflow. It would then be productive. Because of its location it is suitable, however, chiefly for pasture.

## 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 emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and to insure the best crop production.

The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers' organizations of the county should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accumulated in less specific experimental work will be included in or appended to all the reports.

#### *PLANT FOOD IN SOILS*

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

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

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green

manures may be used in practically all cases. Where a crop must be "forced", as in market gardening, some nitrogenous fertilizers may be of value.

#### THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true 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.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

#### AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such 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. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

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

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

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

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitro-

TABLE I. PLANT FOOD IN CROPS AND VALUE

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

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
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

gen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished, care should always be taken that the soil is in the best condition for the growth of bacteria.

#### REMOVAL OF PLANT FOOD BY CROPS

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

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

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

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

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

Of course, if the crops procured are fed on the farm and the manure carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold con-

tain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

#### REMOVAL FROM IOWA SOILS

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

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

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

#### PERMANENT FERTILITY IN IOWA SOILS

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

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

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

#### CULTIVATION AND DRAINAGE

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

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

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

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of heavy drouth may be checked to a considerable extent if the soil is cultivated and a good mulch is main-

tained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

#### THE ROTATION OF CROPS

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

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotation. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under, they not only supply organic matter to the soil, but they also increase the nitrogen content.

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

But, whatever the reason for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be 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.

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 per cent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.



Crop residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter content of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under of leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated and thus increase the nitrogen content of the soil which gives them their great value as green manure crops.

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated or by the use of inoculating materials that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

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

#### THE USE OF PHOSPHORUS

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

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

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils 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 exceptions to the general rule, as was shown by the tests of many representative soils reported in Bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particu-

larly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime; according to simple directions in bulletin No. 151, referred to above.

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

**SOIL AREAS IN IOWA**

There are five large soil divisions in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 11.

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 their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stone. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

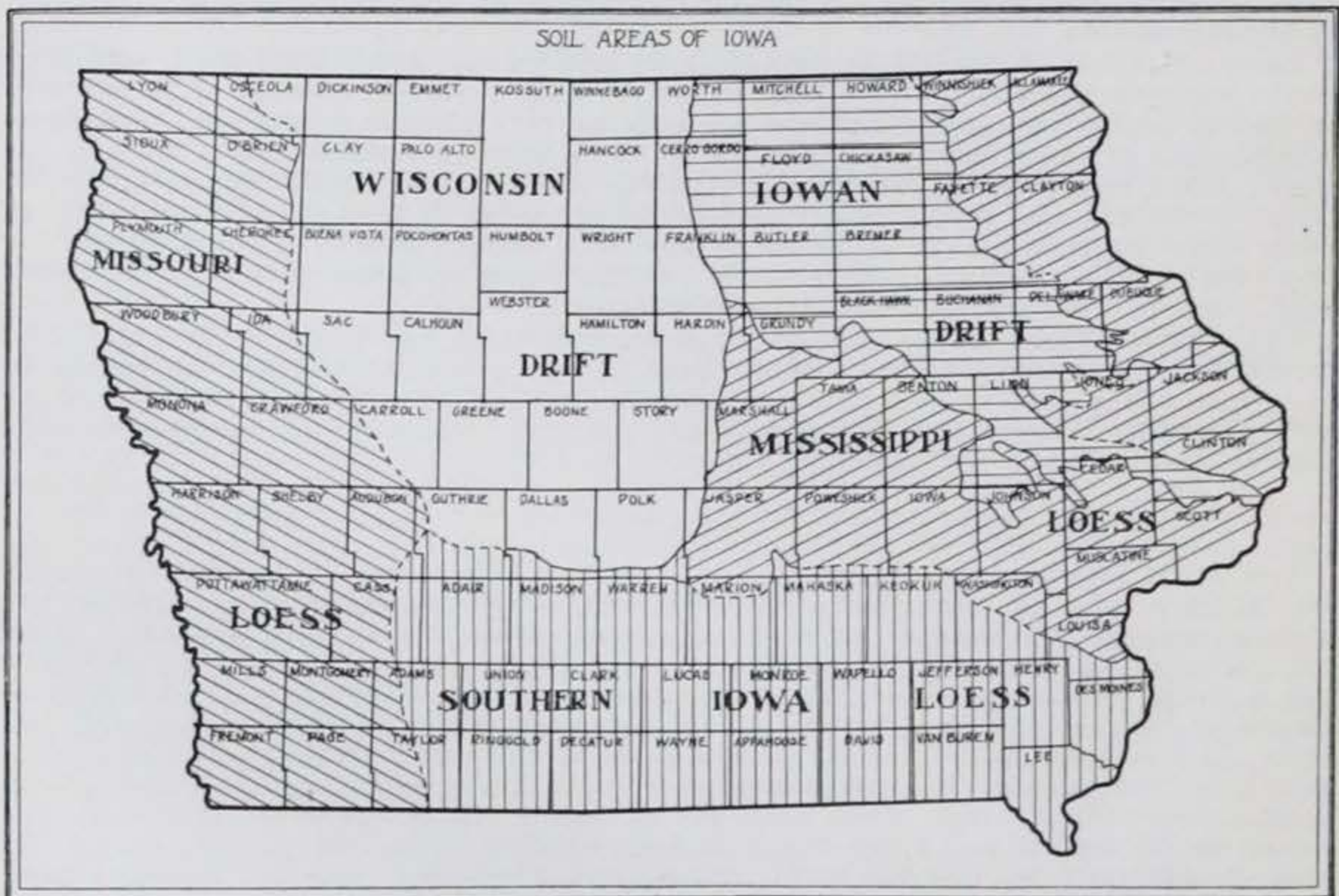


Fig. 11. Map showing the principal soil areas in Iowa.

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

THE SOIL SURVEY BY COUNTIES

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

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

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into soil survey work from this source is very small and need cause 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, coluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical and mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

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

SOILS GROUPED BY TYPES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

#### METHODS USED IN THE SOIL SURVEY

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

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

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

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

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

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

The 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 road map of the county.

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