SOIL SURVEY OF IOWA

MARSHALL COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 25
July, 1922

Ames, Iowa

IOWA AGRICULTURAL EXPERIMENT STATION

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SOIL SURVEY OF IOWA

Report No. 25—MARSHALL COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, E. I. Angell and H. J. Harper

A farm home on the Tama silt loam in Marshall county.

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
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MARSHALL COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, E. I. Angell and H. J. Harper

Marshall county is located in central Iowa, almost in the exact center of the state. It lies partly in the Iowan drift soil area and partly in the Southern Iowa loess soil area. Hence, both drift and loess soils are found in the county, the area covered by loess being very much larger, however, than that occupied by the drift soils.

The total area of Marshall county is 572 square miles or 366,080 acres. Of this area, 339,925 acres or 92.8 percent is in farm land. The total number of farms is 2,260 and the average size of the farms is 150 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the utilization of the farm land in the county:

Acreage in general farm crops	229,127
Acreage in pasture	90,530
Acreage in farm buildings, feedlots and public highways	18,800
Acreage in waste land	1,359
Acreage in crops not otherwise listed	500

The type of agriculture practiced in Marshall county at the present time is very largely livestock farming, altho general farming is perhaps the system most commonly followed. The livestock industry consists of the feeding of hogs and cattle, but the raising of hogs and other livestock is rapidly increasing. Grain farming, at least, in a modified form, is practiced to some extent and dairying is fast becoming an important industry.

The income of the county is derived in large part from the livestock industry, but much of the grain produced is still sold out of the county, and the sale of corn and oats adds materially to the income from the farms. On farms operated by the owners, very little of the grain produced is sold, practically all of it being utilized for feeding, while on tenant farms less feeding is done and much of the corn and oats is sold.

The area in waste land in the county is rather considerable and some method of treatment should be adopted which would permit of the reclamation of these areas. General recommendations for the best treatment of such land cannot be given, inasmuch as the causes of infertility are so variable. In a later section of this report special treatments which are particularly desirable for individual soil conditions will be indicated. In special cases for more or less abnormal soil conditions, advice regarding treatment may be obtained upon request from the Soil Section of the Iowa Agricultural Experiment Station.

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

Corn is the most important crop, both in acreage and value. Slightly over one-third of the total area of the farm land of the county is being devoted to this crop and average yields of 49 bushels per acre were secured in 1920. The most extensively grown variety is White Dent, other varieties grown being Reid's

*See Soil Survey of Marshall county, Iowa, by A. H. Meyer of the United States Department of Agriculture and E. I. Angell of the Iowa Agricultural Experiment Station.

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

Crop	Acres	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	115,000	33.8	49.0	5,635,000	$0.47	$2,648,450
Oats	74,500	21.8	40.0	2,980,000	0.36	1,072,800
Winter wheat	630	0.1	23.0	14,490	1.41	20,430
Spring wheat	2,120	0.6	18.0	38,200	1.35	51,570
Barley	800	0.2	33.0	26,400	0.63	16,632
Rye	90	0.02	20.0	1,800	1.17	2,106
Hay (tame)	34,860	10.2	1.3	45,320	16.24	735,996
Hay (wild)	210	0.05	1.3	273	12.69	3,464
Alfalfa	70	0.02	3.0	210	19.23	4,038
Potatoes	847	0.2	121.0	102,487	1.22	125,034
Pasture	90,530	25.6	....	.....	....	.....

Yellow Dent, Pride of the North, Whipple Yellow Dent, Iowa Silvermine, White Cap Dent and Boone County White. About two-thirds of the corn crop is used for feed on the farms, for hogs and other livestock. On tenant farms, the major portion is sold. On most livestock farms, from 10 to 15 acres of corn is utilized for ensilage. In 1920 there were about 437 silos in the county.

The second crop in acreage and in value in the county is oats. It is grown on 21.8 percent of the farm land and average yields of 40 bushels per acre are secured. The value of the crop is less than half the value of the corn crop. The most popular varieties are the early maturing Iowa 103, Iowa 105, Kherson and Early Champion. The Green Russian is the most widely grown variety, but does not yield as well as the early maturing varieties. Early Amber and Silvermine are also grown to some extent. The greater part of the oats grown in the county is fed to the livestock, the remainder being sold to outside markets.

The third crop in value in the county is hay, clover and timothy constituting the leading hay crop. In 1920, over 10 percent of the total farm land of the county was occupied by tame hay. Only a relatively small acreage is devoted to wild hay. Average yields of clover and timothy amount to 1.3 tons per acre. Besides clover and timothy mixed, timothy is grown alone for hay and on a larger acreage, clover is grown alone. Small areas are devoted to millet and to certain tame grasses. Some red clover seed and timothy seed are produced. Clover yields two to four bushels of seed per acre on the average, and timothy, four to eight bushels. Practically all of the hay is fed to work stock and cattle, only a small amount being sold.

Potatoes are grown on a considerable area in the county and are the fourth crop in value. Average yields of 121 bushels per acre are secured. The main varieties grown are Rural New Yorker, Early Ohio, and some Early Rose. The production of potatoes is quite inadequate to meet the demands of the county and many are shipped in.

The acreage in wheat is rather small, and the amount of this crop produced is insufficient to meet the local demand. Spring varieties are grown more extensively than the winter varieties. The total value of the spring and winter wheat is considerably less than that of corn and oats. Average yields of 23 bushels

*Iowa Yearbook of Agriculture, 1920.

per acre are secured for the winter varieties, chiefly Turkey, and 18 bushels for the spring varieties, Marquis and Java. Barley and rye are grown to a small extent, and alfalfa is also grown on a small area. The value of these crops is not large in the aggregate, but may be considerable on individual farms.

Alfalfa is being produced more extensively and yields of three tons per acre are secured on the average. An increased acreage in this crop will result from a better knowledge of the soil conditions which are necessary for its satisfactory growth. The addition of lime is particularly necessary for alfalfa growing and the conditions must be such that the soil is well drained and aerated.

Other crops of minor importance grown in the county are buckwheat, rape, flaxseed, sweet potatoes, sweet corn, sorghum, Sudan grass, soybeans, popcorn, pumpkins, tomatoes and cabbage. Rather considerable areas are devoted to sweet corn production, especially near Marshalltown and Gilman, the product being utilized by the canning factories in those cities. Stowell's Evergreen is the variety most commonly used, altho Country Gentleman and Early Evergreen are also grown. Sorghum is grown in small patches by many farmers and utilized for sirup and for feed. Some Sudan grass is produced and the seed finds a ready market. This crop makes excellent pasture. Soybeans give promise of becoming an important crop in the future.

Pumpkins, tomatoes and cabbage are produced in quantities near Marshalltown and supplied to the canning factory. The sale of these crops provides considerable income on some farms. Watermelons and cantaloupes also are grown to some extent, and vegetables other than potatoes are produced on rather large areas, particularly near Marshalltown. The trucking industry, however, is not very largely developed in the county.

There are no strictly commercial orchards in the county, but most farmers have a small number of fruit trees, chiefly apples, plums, cherries and pears. These fruits are utilized for home consumption to a large extent, altho in some years there is a rather considerable sale out of the county. Small fruits such as strawberries, blackberries and raspberries are also grown to some extent.

THE LIVESTOCK INDUSTRIES OF THE COUNTY

The livestock industries of the county include dairying and the raising and feeding of cattle and swine. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the numbers of livestock in the county:

Horses (all ages)	14,155
Mules (all ages)	659
Swine (on farms July 1, 1920)	100,868
Swine (on farms Jan. 1, 1921)	76,314
Cattle (cows and heifers kept for milk Jan. 1, 1921)	11,151
Cattle (other cattle not kept for milk Jan. 1, 1921)	33,283
Cattle (all ages)	44,434
Sheep (all ages on farms Jan. 1, 1921)	12,780
Sheep (shipped in for feeding during 1920)	9,567
Sheep (pounds of wool clipped)	69,467
Poultry (total all varieties Jan. 1, 1921)	259,099
Poultry (number of dozen eggs received, 1920)	1,067,176

The dairy industry is receiving an increasingly large amount of attention in the county, and most of the products from dairy farms are supplied to the local creameries, to the local markets and to outside points. Practically all of

the farmers keep dairy cows, chiefly Shorthorns or Holsteins, and in most cases, of course, the dairy products are utilized largely for home consumption. The value of the dairy products of the county has been estimated at over half a million dollars during the year 1920.

The feeding of beef cattle is practiced to a large extent in the county, the stock being sold in the Chicago and Omaha markets. The raising of beef cattle is also an important industry and there are a number of herds of Shorthorns in the county, and some Aberdeen Angus and Hereford herds.

The breeding of farm and draft horses and mules is receiving some attention, nearly every farmer raising one or two colts each year. The Percheron and Belgian are the favorite breeds.

The raising and feeding of sheep has increased to a considerable extent in the county during the past few years and the income from this industry is rather large. Most of the sheep are shipped to Chicago.

The raising of hogs is the most important livestock industry and the number of farmers specializing in it is increasing. Duroc Jersey, Poland China, Chester White, Hampshire and Berkshire are the leading breeds. Practically all farmers raise enough hogs to supply their own demands, and on the livestock farms the raising of hogs constitutes a major source of income, the hogs being marketed in Waterloo, Mason City and Cedar Rapids. According to estimate, in 1920 the value of the hogs on the farms of the county was over $2,000,000.

The raising of poultry is becoming of some importance, and the value of the poultry products is considerable. They are sold in large part to a local firm in Marshalltown and shipped to Chicago, New York and Boston.

The value of the land in Marshall county is rather variable, depending upon the location with reference to towns and to railroad facilities, the improvements on the farms and general soil conditions. The average price of farm land is about $250 per acre. The range in selling price varies from about $50 to $350. In some instances the land has sold at a considerably higher figure than this and it is generally recognized that much of the land in the county is extremely valuable for general farming purposes.

The yields of general farm crops in Marshall county are usually satisfactory, but in many instances proper methods of soil treatment would undoubtedly bring about more profitable yields. The particular treatments which are needed vary somewhat, depending upon the soil conditions or upon the characteristics of the individual soil type. Topography features are also frequently of significance.

In some instances drainage is not entirely satisfactory, and when this is true, the first treatment needed to insure satisfactory crop growth is the installation of tile. No other treatment will be of value if the soil is too wet and whatever the expense involved in putting in tile, the value of the greater crop growth secured will more than make up for the outlay.

The soils of the county are very largely acid and applications of lime are quite generally necessary for the best growth of farm crops, particularly legumes. Only in one instance is there any large occurrence of carbonates in the soil and in this case lime would not, of course, be necessary. In the other instances where a basic reaction has been found, the lime content is small and the surface

soils will soon be in need of applications of this material. All the soils of the county should evidently be tested for lime requirement, especially before any attempt is made to grow legumes.

In some instances, the soils of the county are not very well supplied with organic matter and applications of farm manure and green manures should be made in order to put the soils in better condition for crop growth. In the case of several of the upland types, however, and also in some of the bottomland soils, the amount of organic carbon present seems to be considerable and it might be assumed that these soils would not respond to fertilization with farm manure. In all cases, however, the application of this material has led to increases in crop growth and it may safely be said that on all the soils of the county, farm manure should be applied in liberal amounts, and where it is not available, leguminous green manures should be used. On the light sandy types of soil, the use of these materials is particularly necessary and in many instances other fertilization would be of practically no use until the organic matter content of the soils is built up.

The nitrogen content of the soils is not strikingly low except in one instance, but care should be taken to keep up the supply of this constituent. This may be accomplished thru the use of leguminous green manure crops.

The phosphorus supply is not particularly high in any case, and in most of the soils it is rather low. Need of phosphorus fertilization on the soils of the county, if not acute at the present time, will soon become evident. Applications of phosphorus fertilizers to small areas are suggested at the present time in order to determine whether or not these materials will prove profitable. Acid phosphate and rock phosphate may both be used in such tests to learn which material will prove the most profitable.

Complete commercial fertilizers are not recommended at the present time for the soils of the county, but any who are interested in these materials may include tests of them along with the phosphorus tests.

Erosion is occurring to some extent in Marshall county and it is very desirable that precautions be taken to prevent the extensive washing away of the surface soil and to stop the formation of gullies.

THE GEOLOGY OF MARSHALL COUNTY

The early geological history of Marshall county is of practically no significance from the standpoint of present-day soil conditions. The original bed rock material in the county has been buried so deeply by the glacial deposits that there is no effect of this material upon the soil characteristics.

At least three times during the glacial age great glaciers invaded the county and each time, upon their retreat, left behind an enormous mass of glacial drift or till, which covered the entire surface of the land. The topographic features of the county which had been established prior to the coming of the glaciers were very largely obliterated at the first invasion. Later glacial action remodeled, to a large extent, the topographic features developing in the earlier drift deposits and covered them with deep layers of new drift. Hence there is found over the surface of the county layers of drift of varying depths, representing the glacial material laid down by the various ice sheets.

The earliest drift deposit is known as the Kansan and it varies in different parts of the county from a few feet to a hundred feet in thickness. This drift material is underlaid in some places by layers of stratified sand and gravel containing many pebbles and small boulders. This layer may extend to a depth of thirty feet. The Kansan deposit is composed mainly of boulder clay, varying in color from a bright yellow to a deep reddish-brown, where exposed to oxidation, and to a blue when unoxidized. Pockets of sand and gravel occur and boulders are frequently found.

Following the retreat of the Kansan ice sheet, beds of gravel known as the Buchanan gravels accumulated, and remains of these gravel beds occur in some parts of the county.

At a later date a second glacier invaded the county, crossing the northeastern corner. The deposit left by this glacier is known as the Iowan drift and it usually extends to a depth of not more than 10 feet. It is light to bright yellow in color and is sandier than the Kansan drift. Boulders, usually of a larger size than those found in the Kansan till, are of frequent occurrence. The entire drift material shows its more recent origin and hence there is less evidence of weathering.

Still later, a third glacier crossed the western part of the county, depositing, upon its retreat, a layer of drift known as the Wisconsin. The upper part of this drift material is a dull yellow in color and apparently has been leached to a much less extent than the Iowan and Kansan drift material. In the lower parts it is a blue boulder clay, less impervious, however, than the Kansan. Boulders are very common in this drift material and consist mainly of granite. In most cases the material below a depth of four feet effervesces with hydrochloric acid, indicating the occurrence of carbonates. This is the only drift material which is exposed at the surface over any extensive areas in the county. The Carrington loam is derived from this Wisconsin till and this type is found mainly along the western edge of the county.

Following the glacial age there was a deposition of loess over practically all of the county with the exception of the western portion just noted. This layer of loess is extremely variable in depth, ranging from a few inches to 20 feet.

Along the streams and in the rougher portions of the county, the loess covering has been removed to a considerable extent and there are areas of soils of the Shelby and Lindley series which are derived practically entirely from the underlying drift material. The loess soils of the county are classed in the Tama, Muscatine, Knox and Clinton series.

In its unweathered condition, loess is an even-grained material, composed largely of silt. It ranges in color from a light grayish-brown to a yellowish-brown. Organic matter has accumulated quite generally in the surface soils and there has been a development of a darker soil. Under prairie conditions abundant plant growth, with the resultant vegetable residues, has led to the formation of almost black soils. The Muscatine and Tama soils, the leading loess types in the county, are quite generally dark brown to black in color. Where the loess has weathered under wooded conditions, erosion has been active and more leaching has occurred. Organic matter has not accumulated to such

SOIL MAP OF MARSHALL COUNTY

Thomas D. Rice, Inspector, Northern Division. Soils surveyed by A. H. Meyer, of the U. S. Department of Agriculture, in charge, and E. I. Angell of the Iowa Agricultural Experiment Station.

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

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

LEGEND

Drift Soils

- 1 — Carrington loam
- 79 — Shelby loam
- 65 — Lindley loam
- 4 — Carrington fine sandy loam
- 85 — Clyde silty clay loam

Loess Soils

- 120 — Tama silt loam
- 30 — Muscatine silt loam
- 80 — Clinton silt loam
- 141 — Knox loamy fine sand

Terrace Soils

- 75 — Waukesha silt loam
- 38 — Buckner loam
- 43 — Bremer silty clay loam

Swamp and Bottomland Soils

- 26 — Wabash silt loam
- 49 — Wabash loam
- 48 — Wabash silty clay loam
- 21A — Muck

Scale: 1 Inch 2½ Miles

MIDLAND MAP AND ENGINEERING CO. DES MOINES, IOWA

a large extent and the soils are lighter in color, varying from a gray to light brown. This is true of the Clinton and Knox series.

The variation in fertility in these loess soils is considerable, depending upon the topographic conditions, the drainage and the character of the plant growth. Thus, the Muscatine and Tama soils are much richer than the Clinton and Knox types. In all cases lime has been practically entirely removed from the surface soil and these types are all in need of lime.

In addition to the upland soils, which are either of loessial or drift origin, there are considerable areas of terrace or second bottom soils and of first bottoms. These are very largely made up of loessial material washed down from the uplands.

PHYSIOGRAPHY AND DRAINAGE

In topography Marshall county consists in general of three distinct divisions, which correspond rather closely with the areas covered by the Wisconsin, the Iowan and the Kansan drifts.

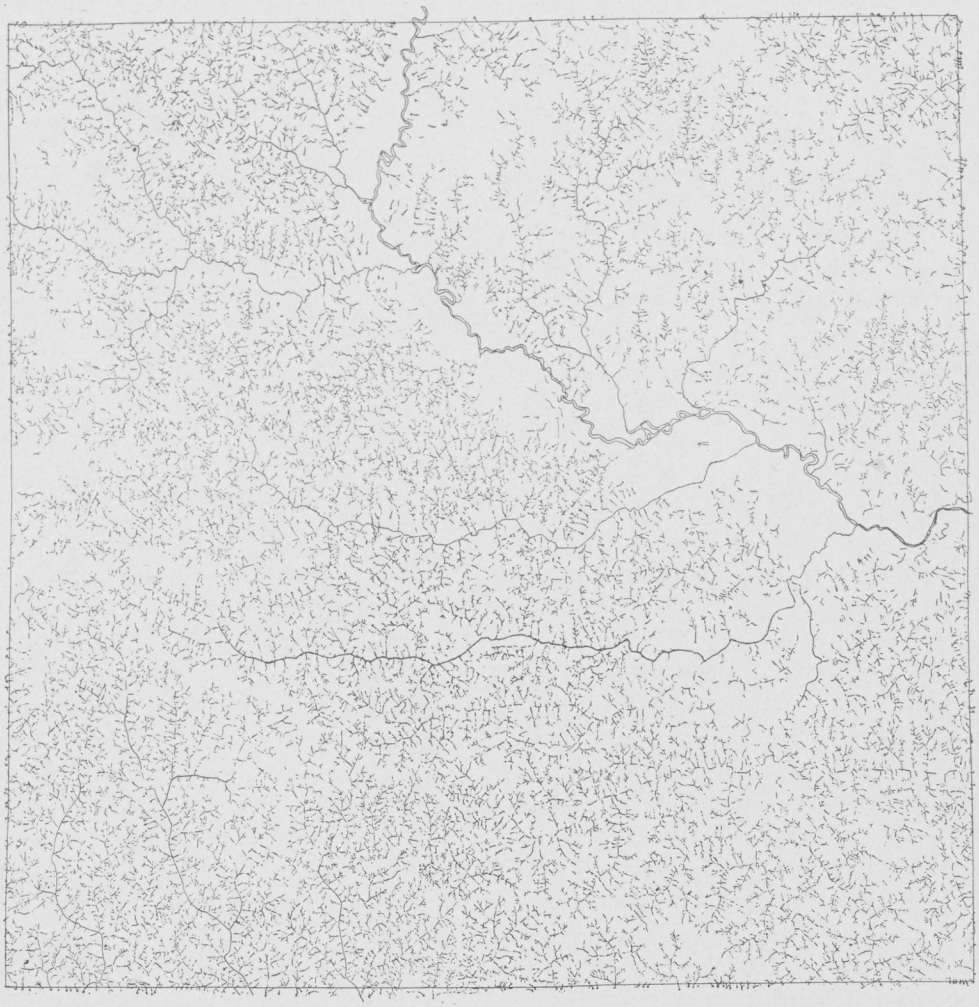

Fig. 1. Map showing natural drainage system in Marshall county.

The first division, occupied by the Wisconsin drift, consists of an irregular-shaped area in the western part of the county, beginning with a very narrow area at the southern boundary of the county and broadening to a width of over three miles in the center of the county and narrowing again to about two at the northern boundary. The physiographic features of this area include many depressions and sloughs, small knolls and hills, and other surface features which indicate that the drainage of the area is imperfect and that leaching of the soils has not been so great. In some places on the western edge of the area, there appear evidences of the terminal moraine and in general there is a distinct line of division between this more recently glaciated area and the older areas to the east.

The second division, occupied by the Iowan drift, covers an area about 50 square miles in size in the northeastern corner of the county. The topography of this area is characterized by a rather level surface, broken by small depressions and gentle elevations. The region is in general fairly well drained.

The third topographic division of the county includes more than four-fifths of the total area. This represents the oldest or Kansan drift area. The upland in this area is covered by a net work of small streams, short V-shaped valleys and more pronounced hills. The larger streams flow thru broad valleys and the uplands between are rolling in topography. Some areas appear to contain small hills, while others are rather flat, but these hills and upland flats have about the same general level. Shallow depressions are found in the larger, flatter areas. Apparently the entire area was originally a narrow level plain and the topographic features which have been developed are the result of erosion during the years which have elapsed since the glaciation and the deposition of the loess.

The major portion of the bottomland of the county is found along the Iowa river and its tributaries. These areas are in general level, altho the surface is frequently broken by depressions, sloughs and old channels of the stream. Terraces or second bottom soils occur along the larger streams, but they are comparatively small in extent. They lie from 5 to 20 feet above the present flood plain of the streams, and are flat and very slightly eroded.

The drainage of the county is brought about mainly by the Iowa river and its tributaries. About four-fifths of the county is drained in this way. Perhaps three square miles in the northeastern part of the county is drained by Wolf creek, which runs into the Cedar river, while the southwestern part of the county is drained by the north Skunk river. The Iowa river flows across the county from northwest to southeast and the larger tributaries are Timber creek, Linn creek, Minerva creek and Honey creek, draining the area west of the river, and Chicken creek, Asher creek, Burnett creek and Rock creek, draining the area north and east of the river. There are numerous minor streams which are tributary to these larger creeks and there is practically none of the county which cannot be drained easily by means of the natural drainage ways. The drainage system of the county is quite complete and, where the soil is not properly drained, the installation of tile is all that is needed to bring about entire removal of excess moisture. The bottomlands of the county overflow annually, but in most seasons these overflows bring about no serious injury

and the bottomlands are cropped and yield satisfactorily. Infrequently destructive floods occur and when this happens the bottomlands of the county cannot be used for cropping purposes.

THE SOILS OF MARSHALL COUNTY

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

Drift soils are formed from the materials carried by glaciers and deposited on the surface of the land when the glacier retreated. They are extremely variable in composition and contain pebbles and frequently boulders. Loess soils are fine, dust-like deposits made by the wind at some time when climatic conditions were very different than they are at present. Terrace soils are old bottomlands which have been raised above overflow by decreases in the volume of the streams which deposited them, or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low, poorly-drained areas or along streams and are subject to more or less frequent overflow. The extent and occurrence of these four groups of soils in Marshall county are shown in table II.

Over one-half of the total area of the county, 67.7 percent, is covered by loess soils, the area of uplands covered by this group including practically the entire central portion of the county. The drift soils cover 19.8 percent of the total area of the county and occur mainly along the western boundary. Terrace soils are of only minor occurrence, together covering 2.9 percent of the county, and swamp and bottomland soils are found covering 9.6 percent of the total area, the larger areas of these soils occurring along the Iowa river.

There are fifteen individual soil types in the county and these, together with the area of muck, make a total of sixteen separate soil areas. There are five drift soils, four loess types, three terrace soils and four areas of swamp and bottomland. These various soil types are distinguished by certain characteristics which are described in the appendix to this report, and the names denote certain group characteristics. The areas of the various soil types in the county are given in table III.

The Tama silt loam is the largest individual soil type, covering over half the total area of the county. The Carrington loam is the largest drift soil and the second largest soil type, covering, however, but 10.2 percent of the total area. The Shelby loam is the third largest type and the second largest drift soil, covering 7.0 percent of the total area. The Wabash silt loam is the largest bottomland soil and the fourth type in the county, being only slightly smaller

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

Soil group	Acres	Percent of total area of county
Drift soils	72,576	19.8
Loess soils	247,872	67.7
Terrace soils	10,688	2.9
Swamp and bottomland soils	34,944	9.6
Total	366,080	100.0

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN MARSHALL COUNTY

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
1	Carrington loam	37,440	10.2
79	Shelby loam	25,792	7.0
65	Lindley loam	3,584	1.0
4	Carrington fine sandy loam	3,136	0.9
85	Clyde silty clay loam	2,624	0.7
	LOESS SOILS		
120	Tama silt loam	217,600	59.4
30	Muscatine silt loam	17,792	4.9
80	Clinton silt loam	10,816	2.9
141	Knox loamy fine sand	1,664	0.5
	TERRACE SOILS		
75	Waukesha silt loam	5,184	1.4
38	Buckner loam	4,800	1.3
43	Bremer silty clay loam	704	0.2
	SWAMP AND BOTTOMLAND SOILS		
26	Wabash silt loam	25,536	7.0
49	Wabash loam	5,248	1.4
48	Wabash silty clay loam	4,096	1.1
21a	Muck	64	0.1

in extent than the Shelby loam. The Muscatine silt loam is the next type in area and the second loess soil, covering 4.9 percent of the county. The Clinton silt loam is much smaller in extent and covers 2.9 percent of the county. The remaining soil types are all very minor in area, many of them covering less than 1 percent of the county. The terrace soils are all minor in area, the largest of these occupying only 1.4 percent of the county.

The upland soils of Marshall county are quite generally undulating to rolling in topography. This is characteristic of the Tama and Clinton soils of the loess soil group and also of the Carrington and Shelby soils of the drift soil group.

The Clyde silty clay loam, a drift soil, and the Muscatine silt loam, a loess soil, are more level in topography and are characterized by less adequate drainage systems. In the terrace and swamp and bottomland soil groups, the soils of the Bremer and Wabash series are level in topography and, in general, poorly drained. The Waukesha soils and Buckner soils are better drained and gently undulating in topography.

In some parts of the county the topography is almost rough. This occurs where the soils are in the Lindley series and sometimes where the Shelby and Clinton soils are found. The Carrington fine sandy loam and the Knox loamy fine sand, both very minor in extent, have the gently rolling topography of the major upland soils of the county. As has been noted, the topographic condition of the county, together with the rather complete drainage system, permits adequate drainage of most of the soils.

THE FERTILITY IN MARSHALL COUNTY SOILS

Samples were taken for analyses from each of the soil areas in the county, except the area of muck. The more extensive types were sampled in triplicate, while only one sample was taken in the case of the minor types. All samplings

were made with the greatest care that the samples should be representative of the particular soil types and that variations due to local conditions or previous treatment should be eliminated. 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 made in all cases for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The phosphorus, nitrogen and carbon determinations were made according to the official methods, and the Veitch method was followed for the limestone requirement determinations. The figures given in the tables are the averages from the results of duplicate determinations on all 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 various soil types in the county is quite variable, ranging from 612 pounds per acre in the Knox loamy fine sand up to 2,027 in the case of the Clyde silty clay loam. There is no distinct relationship apparent between the phosphorus content of the soils within the four groups. The average of the bottomland soils is slightly higher than that of the other groups, which might be expected, inasmuch as the crop production on these types has been limited and there has been very much less removal of this constituent than takes place normally on cropped soils on the upland. The terrace types are slightly higher than the loess and drift soils, on the average, but the differences are in general too small to permit of definite conclusions. In fact, the variations within the various soil groups are larger than the variations between groups. Thus, there is a range from 976 pounds to 2,027 among the drift soils, and the loess types range from 612 to 1,430 pounds.

TABLE IV. PLANT FOOD IN MARSHALL COUNTY, IOWA, SOILS
Pounds per acre of 2,000,000 pounds of surface soil (0″—6 2-3″)

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
1	Carrington loam	976	3,880	44,820	0	3,864
79	Shelby loam	1,097	3,068	31,780	0	2,318
65	Lindley loam	1,212	1,766	16,658	32,042	Basic
4	Carrington fine sandy loam	1,097	2,270	29,160	0	2,705
85	Clyde silty clay loam	2,027	5,884	77,698	1,402	Basic
	LOESS SOILS					
120	Tama silt loam	1,430	6,010	73,338	263	1,030
30	Muscatine silt loam	1,279	5,520	68,400	0	4,250
80	Clinton silt loam	1,225	3,418	41,020	0	773
141	Knox loamy fine sand	612	532	7,580	0	1,932
	TERRACE SOILS					
75	Waukesha silt loam	1,528	4,190	47,140	0	4,637
38	Buckner loam	1,097	3,320	42,800	0	3,478
43	Bremer silty clay loam	1,775	4,644	58,952	2,128	Basic
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,899	6,894	80,680	0	2,318
49	Wabash loam	1,003	3,404	40,206	2,854	Basic
48	Wabash silty clay loam	1,724	6,010	71,140	0	1,159

When the individual soil types are considered, however, there seems to be some relation between the phosphorus content and the soil series and texture. Thus, the silty clay loams are generally considerably higher in phosphorus than the lighter textured types. This is probably due, in large part, at least, to the fact that soils of this texture are more level in topography and apt to be inadequately drained. Hence crop growth has been reduced and the removal of the original stock of phosphorus has been less rapid. Among the bottomland soils the Wabash silt loam is slightly higher than the silty clay loam, but the topographic and cropping conditions on these bottoms is such that the effect of the soil texture would naturally be less evident. Fine sandy loams and other light textured types would naturally be low in phosphorus, as well as in other plant food. The loams seem to be lower in phosphorus than the silt loams, even when they are of different series. This would not always hold true, however, and generally comparison should only be made within the series. In general, these analyses bear out the belief that the heavier textured soils are apt to be richer in plant food constituents than the lighter textured types.

It is evident from the figures given that the phosphorus supply of the soils of Marshall county is rather low in many cases and phosphorus fertilizers will undoubtedly be needed on these soils in the near future if satisfactory crop yields are to be secured. Even if these materials are not absolutely necessary at the present time, phosphorus must be taken into account in planning systems of permanent fertility. Of course, there is never any assurance from analyses that sufficient phophorus would be produced in an available form from any soils, but when the general soil conditions are satisfactory, it may generally be assumed that a fairly rapid production of the element in an available form will occur. When the total supply is as low as is the case in many of the soils of this county, however, it is safe to say that the supply of available phosphorus would probably be insufficient in many cases. It seems probable, therefore, that phosphorus fertilizers might be used with profit on some of these soils at the present time. Individual farmers are urged to test phosphorus fertilizers on small areas on their own farms and thus determine for their own conditions whether or not these materials are profitable. Small areas may be treated with a phosphorus fertilizer and if crop yields are increased profitably, then the same material may be applied to larger areas with assurance of profit.

The nitrogen content of the soils of the county is even more widely variable than the phosphorus supply, ranging from 532 pounds in the case of the Knox loamy fine sand, up to 6,894 pounds in the Wabash silt loam. In general the soils of the county do not seem to be strikingly deficient in nitrogen, with the exception of the Knox loamy fine sand mentioned above. The Lindley loam, while not so low as the Knox loamy fine sand, is not very well supplied with nitrogen and the Carrington fine sandy loam likewise is not particularly rich in this constituent. Most of the silt loams, loams and silty clay loams of the upland, however, are fairly well supplied.

There is no relation between the amount of nitrogen present in the soils of the various soil groups, altho the average of the bottomland soils is higher than that of the other groups, which might be expected for the same reasons which

were suggested in the case of phosphorus. There is some evidence, however, of a relationship between the soil texture and the nitrogen. As in the case of phosphorus, the heavier textured types generally contain more nitrogen. The silty clay loams and silt loams are better supplied with this constituent than the loams, and the latter soils are much richer than the sandy types.

While it is evident from these analyses that, except for one or two minor types, the soils of the county are not extremely low in nitrogen, this element must not be neglected in planning systems of permanent soil fertility. The treatments practiced in the case of all the soils must include the addition of nitrogenous fertilizing materials if the supply of this element is not to become deficient. Farm manure returns to the soil considerable amounts of nitrogen that have been removed by crop growth, and it constitutes, therefore, a very important fertilizing material from the nitrogen standpoint. Crop residues likewise return a portion of the nitrogen taken from the soil. Both these materials aid in keeping up the supply of nitrogen, but by their use alone there is a constant decrease in nitrogen in the soil, owing to the fact that complete return cannot be made. Leguminous green manures are often used as supplements to or substitutes for farm manure and they increase the nitrogen supply in the soil by utilizing the free nitrogen of the atmosphere. This is only accomplished when the legumes are inoculated, and the actual amount of nitrogen added is extremely variable, depending upon many factors, such as thoroness of inoculation, character of the crop grown, and nitrogen content of the soil. For the clovers it is believed that the nitrogen content of the tops is equal to that taken from the air and hence the supply in the soil is increased by an amount which is determined by the size of the crop. Leguminous green manures constitute the cheapest and best source of nitrogen and the practice of green manuring is of value in building up soils low in nitrogen, and in keeping up the supply of this constituent.

The supply of nitrogen in soils may be increased, therefore, by the use of farm manures, crop residues and leguminous green manures, but these materials have an additional value in that they also keep up the supply of organic matter or organic carbon in soils. In fact, there is a distinct relation between the nitrogen and organic carbon in soils. The content of both these constituents is rather definitely indicated by the color of the soil. If it is black, the organic carbon and nitrogen content is high. If it is light, the supply of these constituents is low.

The soils of this county show a wide variation in organic carbon content and in the case of each type there is rather definite relation to the nitrogen supply and also to the color of the soil. Where the nitrogen is low, the organic carbon is likewise low. Where the nitrogen is high, there is a large amount of organic carbon present. Again, there is no relation between the supply of this constituent and the various soil groups. There is, however, a relation between the texture of the individual soils and the organic carbon content, just as in the case of nitrogen. The heavier textured soils are high in organic carbon, while the light textured types are low in this constituent. The heavier textured types are all dark in color, so that there is the same relationship between the organic carbon content and the color of the soil.

The relation between the carbon and nitrogen present in soils gives rather definite evidence of the rate at which plant food is being made available. In practically all cases the relation between these constituents in the soils of Marshall county is satisfactory. In two or three instances, however, the relation is not the most desirable one. In these instances applications of farm manure would prove particularly valuable because of the fact that this material brings about a more rapid decomposition of organic matter and a greater production of available plant food. This does not mean that farm manure would not be of value on any of the soils in the county, but merely that its effects are more pronounced where there is stimulation in the available plant food production. In fact, the use of farm manure on the soils of the county is strongly to be urged, even where the organic matter content is rather high and the color is quite dark. This material will prove of considerable value in all cases, as is evidenced by the results of field tests and much farm experience, and it should be applied in as liberal amounts as possible. If there is not sufficient manure available to apply to all the soils on the farm, leguminous green manures should be used to make up the deficit. All crop residues should also be used on these soils in all cases. It should be clearly understood that if the soils are to be kept up in fertility and if they are to be made as highly productive as possible, the organic matter supply must be maintained carefully.

Several of the soils of the county show a small content of inorganic carbon, but only in one instance is the amount of this constituent very considerable. The Lindley loam shows a rather high content and the amount present in this case is sufficiently large so that it will be some time before acidity develops. Where inorganic carbon is present, even tho only in small amounts, there is no lime requirement shown by the tests, except in one instance where the inorganic carbon is hardly more than a trace and the acidity is very slight. Four of the soil types give a basic reaction and hence indicate that lime would not be necessary for application at the present time, but as the inorganic carbon content is low, the soils will soon become acid and will need lime. In the types where acidity has developed, the lime requirement of the particular samples is extremely variable.

There is no relation between the limestone requirement, as shown in the table, and the soil group, soil series or texture, and, indeed, the determinations which are constantly being made on many samples from all over the state indicate that there may be wide variations in acidity in different samples of the same soil type. The figures given in the table, therefore, should be considered merely indicative of the needs of the soil types and should not be taken as recommendations for field treatments of these soils. They do indicate, however, that many of the soils of the county should be tested for acidity and lime requirement, and even in those instances where the particular test reported showed the soils to be basic, tests will be necessary in the near future as, with one exception, the supply of inorganic carbon is not high. Lime disappears from soils rather rapidly when they are under cultivation and well drained, and it is constantly necessary to resupply to soils the lime which is removed by leaching and cropping. If the soils of this county are to produce the most profitable yields of all crops and particularly of legumes, they should

be tested for acidity at regular intervals, at least once in every four-year rotation, and the lime shown to be necessary should be applied.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils appear 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.

Unless there is a very large amount of plant food present in the lower soil layers, there is very little effect upon the fertility of the soil, and hence the analyses of the surface soils are usually sufficient to indicate the plant food supply of the soil and indirectly its crop-producing power. The lower soil layers in Marshall county do not seem to be very high in any of the plant food constituents determined and hence the fertility of the soils will be very little influenced by the varying subsoil conditions. It is hardly necessary, therefore, to consider these results in detail. The needs of the individual soils, as indicated by the results of the analyses of the surface soils are very largely borne out by the results in these lower soil layers. Phosphorus fertilizers will certainly be needed in the future. They might be of value in some cases at the present time. The supply of organic matter and nitrogen must be increased in some instances, and kept up in all cases, by the use of farm manure, crop residues and leguminous green manure.

In general, the soils which react basic at the surface show the same reaction in the lower layers, in one or two instances the amount of inorganic carbon present increasing in the subsoil. In two cases soils which were acid at the surface gave a basic reaction in the lower layers, but in neither instance was there any considerable amount of inorganic carbon present. Only in the Lindley loam, the same soil which showed a high content of inorganic carbon in the surface, is there any considerable supply of this constituent in the lower

TABLE V. PLANT FOOD IN MARSHALL COUNTY, IOWA, SOILS
Pounds per acre of 4,000,000 pounds of subsurface soil (6 2-3″—20″)

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem't
	DRIFT SOILS					
1	Carrington loam	1,670	6,556	78,560	0	5,410
79	Shelby loam	1,898	3,504	39,360	0	3,864
65	Lindley loam	2,114	1,008	2,288	91,912	Basic
4	Carrington fine sandy loam	1,427	3,420	32,800	0	3,864
85	Clyde silty clay loam	2,195	2,352	39,368	592	Basic
	LOESS SOILS					
120	Tama silt loam	2,016	6,901	88,363	330	1,546
30	Muscatine silt loam	1,697	6,248	74,680	0	5,410
80	Clinton silt loam	2,222	2,296	22,880	0	1,546
141	Knox loamy fine sand	1,454	794	6,580	900	Basic
	TERRACE SOILS					
75	Waukesha silt loam	2,451	6,220	79,360	0	7,728
38	Buckner loam	2,263	5,688	68,160	0	1,546
43	Bremer silty clay loam	1,879	6,388	84,444	256	773
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	2,680	7,788	98,000	0	6,182
49	Wabash loam	2,451	5,996	74,292	5,628	Basic
48	Wabash silty clay loam	2,438	6,892	95,692	508	Basic

TABLE VI. PLANT FOOD IN MARSHALL COUNTY, IOWA, SOILS
Pounds per acre of 6,000,000 pounds of subsoil (20″—40″)

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
1	Carrington loam	2,343	4,542	49,980	0	5,796
79	Shelby loam	2,606	2,268	25,680	0	6,954
65	Lindley loam	3,374	924	1,944	136,980	Basic
4	Carrington fine sandy loam	1,777	3,318	40,860	0	3,577
85	Clyde silty clay loam	3,232	2,520	33,078	1,002	Basic
	LOESS SOILS					
120	Tama silt loam	2,643	6,446	73,127	793	3,091
30	Muscatine silt loam	1,737	4,962	62,940	0	3,577
80	Clinton silt loam	4,222	2,520	29,040	0	3,577
141	Knox loamy fine sand	2,081	714	7,513	1,307	Basic
	TERRACE SOILS					
75	Waukesha silt loam	3,636	4,752	49,620	0	4,638
38	Buckner loam	2,424	5,382	53,700	0	3,577
43	Bremer silty clay loam	2,879	4,161	51,718	1,092	Basic
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,878	4,668	82,800	0	3,577
49	Wabash loam	4,283	12,780	158,354	5,206	Basic
48	Wabash silty clay loam	3,051	4,374	71,709	711	Basic

soil layers. Hence, the conclusions drawn from the surface soil would apply equally to the subsoil. In fact, the amount of lime present in the subsoil is of very little significance in reducing the acidity of the soil. Lime generally moves downward in the soil and if the surface soil is acid, lime must be applied regardless of the content of the subsoil. In general, it may be concluded that the soils of Marshall county should be tested at regular intervals for acidity and, when acid, lime should be applied as needed, without considering the subsoil conditions.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Marshall county in order to secure indications of the fertilizer needs of the soils and to learn the value of the application of certain common fertilizing materials. These experiments were carried out on the Tama silt loam and the Carrington loam, two of the more important types in the county. The results of experiments on the Tama silt loam from Black Hawk county and the Carrington loam from Bremer county are also included, inasmuch as they very largely confirm the experiments on the same types in Marshall county. The plan of all these experiments was much the same, with the exception of the test on the Bremer county soil.

The treatments used were manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. The size of the applications was the same as used in the field tests and hence the results of these greenhouse experiments may be considered definitely indicative of the results which may be secured in the field. Manure was applied at the rate of 8 tons per acre. Lime was added in sufficient amounts to neutralize the acidity of the soil as indicated by the Veitch test, and 2 tons additional were supplied in order to put the soil in the best condition for crop growth. Rock phosphate was applied at the rate of

Fig. 2. Greenhouse experiment with clover in Tama silt loam in Marshall county.

2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of complete commercial fertilizer at the rate of 300 pounds per acre.

In the experiment on the Carrington loam from Bremer county, manure was applied at the rate of 10 tons per acre, lime as in the other tests, rock phosphate at the rate of 1,000 pounds per acre and acid phosphate at the rate of 300 pounds per acre. Wheat and clover were grown in all the experiments except on the Carrington loam from Bremer county, clover being seeded about one month after the wheat was up. In the experiment on the Bremer county soil, wheat alone was grown.

The results of the experiment on the Tama silt loam from Marshall county are given in table VII, the figures being the averages of the yields on the duplicate pots. Manure showed a very distinct effect on the wheat grown on this soil, but apparently had little influence on the clover. The application of lime in addition to manure had little effect on the wheat, but increased the clover yield. This is what would be expected, inasmuch as lime rarely increases the yields of grain crops, but the beneficial effects of the material are usually quite evident on the legumes grown in the rotation. Rock phosphate had little effect on the wheat, but showed some influence on the clover. Acid phosphate increased the wheat yield and brought about a considerable increase in the

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

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	19.75	45.36
2	Manure	23.00	45.36
3	Manure+lime	23.50	49.89
4	Manure+lime+rock phosphate	24.00	54.43
5	Manure+lime+acid phosphate	27.50	72.63
6	Manure+lime+complete commercial fertilizer	24.00	63.50

Fig. 3. Wheat and clover on Tama silt loam, Marshall county.

clover. The complete commercial fertilizer showed little effect on the wheat, but increased the clover yield. The increase was smaller, however, than that brought about by the acid phosphate.

It is apparent from these results that manure is a valuable fertilizing material for use on this soil and applications of this material should be made at regular intervals if crop yields are to be increased and the fertility is to be kept up. Lime should be applied when the soil is acid in reaction, if the best crops of legumes are to be grown. It seems quite probable that applications of phosphorus fertilizers would be of value on this soil, as is indicated by the effect of the acid phosphate, particularly. It may be noted that the acid phosphate showed up better than the other phosphorus fertilizers on both wheat and clover, the clover responding more definitely to the rock phosphate and complete commercial fertilizer, however, than did the wheat. It would evidently be very desirable for farmers to test the use of these materials on their own soils and determine the value of phosphorus and which particular phosphorus carrier would yield the greatest profit. No definite conclusions regarding the relative merits of these materials should be made from these greenhouse tests.

The second greenhouse experiment was on the Carrington loam from Marshall county. The results of this experiment are given in table VIII.

Again on this soil the beneficial effect of manure is shown very distinctly by the increased yield of wheat and the increased yield of clover. Lime in addition to manure had little influence on the wheat and the results for clover should not be considered, inasmuch as a slightly smaller yield is shown than with the manure alone. Evidently there was some disturbing factor in this particular case which reduced the clover yield. Rock phosphate, acid phosphate and the

TABLE VIII. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, MARSHALL COUNTY

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

complete commercial fertilizer all gave distinct increases in yields of both wheat and clover, there being very little differences between their effects in the case of the former crop. The acid phosphate showed up quite a little better with the clover. The results, however, would not warrant choosing between these phosphorus carriers and should not be interpreted too broadly.

It is evident that on the Carrington loam, as on the Tama silt loam, manure is an extremely valuable fertilizing material. Lime did not show up in this particular test, but there is abundant evidence to prove that this material will increase the yield of legumes in the rotation when applied to acid soils. Phosphorus fertilizers apparently may be used in some instances with profitable results. Just which material should be chosen must be determined for individual conditions.

The third experiment carried out on the Tama silt loam from Black Hawk county gives very similar results to those secured on the same soil type from Marshall county. The results of this experiment are given in table IX.

The results from this experiment indicate a very definite value from the application of manure, especially in the case of the clover crop, almost four

Fig. 4. Wheat and clover on Carrington loam, Marshall county.

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

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

times as large a crop being secured when the manure was used. Little effect was shown on the wheat and the same is true of the application of lime. This latter material, however, as in the other experiment on the Tama silt loam, brought about a large increase in the clover crop. Rock phosphate increased the yield of wheat and likewise of clover. Acid phosphate had less effect on the wheat, but increased the clover crop considerably. The complete commercial fertilizer also increased the yields of both crops, showing more effect than the acid phosphate on the wheat, but less than the acid phosphate on the clover.

As was concluded in the earlier test, the application of manure to this particular soil is evidently a most desirable operation. Lime should be used when the soil is acid, and will undoubtedly benefit legumes. Phosphorus fertilizers might probably be applied with profit in many cases. Just when those materials should be used must be determined by experiments on individual farms.

The results of the fourth greenhouse experiment on the Carrington loam from Bremer county are given in table X.

These results again show very definitely the beneficial effect of applications of manure, the yield of wheat being more than doubled when manure was applied to this soil in addition to lime. Lime increased the wheat to a slight extent in this case, and the addition of phosphorus along with lime brought about further increases. When either acid phosphate or rock phosphate was used with manure, the rock seemed to be preferable, but when used without manure, acid phosphate gave the larger effects. It is apparent that the Carrington loam will respond to applications of manure and, when acid, lime will

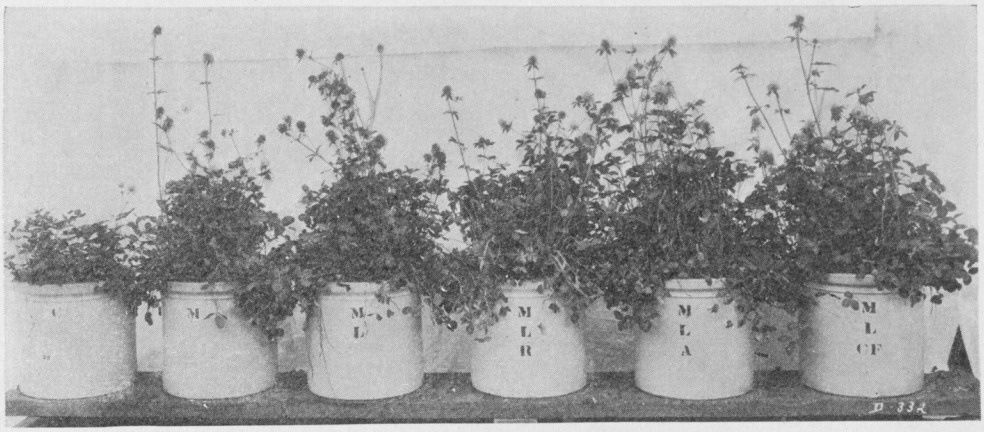

Fig. 5. Greenhouse experiment with clover on Tama silt loam in Black Hawk county.

TABLE X. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, BREMER COUNTY

Pot No.	Treatment	Weight of wheat grain in grams
1	Check	8.25
2	Lime	9.25
3	Lime+acid phosphate	11.25
4	Lime+rock phosphate	9.50
5	Lime+manure	19.00
6	Lime+manure+acid phosphate	18.75
7	Lime+manure+rock phosphate	20.50

prove of value. Phosphorus fertilizers may prove profitable materials for use at the present time and will certainly be needed in the near future.

These greenhouse experiments as a whole indicate that the most desirable soil treatments for the Tama silt loam and the Carrington loam, the two major types in the county, consist in the use of manure and lime and probably phosphorus. Farm manure seems to be of especially large value and if this material cannot be applied in sufficient amounts, probably green manures should be used. Lime is of value when the soil is acid, particularly for the growth of legumes, and phosphorus fertilizers may be of value in some cases at the present time and will certainly be needed in the future. The kind of phosphorus fertilizers which should be used must be determined by the carrying out of special tests on individual soils and farmers are urged to test the use of these materials on their own soils on a small scale and, if favorable results are secured, the same materials may then be used on larger areas with the assurance of profit.

FIELD EXPERIMENTS

Several field experiments are just being started in Marshall county and it will be some time before the results secured on them will be available for publication. However, experiments have been under way for several years in nearby counties on the same soil types which occur most extensively in this county, and the results which are being secured on some of these fields will be included here, inasmuch as they undoubtedly indicate the nature of the results which may be expected from the experiments in Marshall county. The results of these experiments will serve to emphasize the needs of the soils of Marshall county and will also call attention to the desirability of testing certain fertilizing materials in the county and determining their value.

These field experiments are all planned with the idea of determining the relative value of various soil treatments and they are laid out on land which is entirely representative of the most important individual soil types in the county. They are permanently located by the installation of corner stakes and every precaution is taken in the application of fertilizers and in the harvesting of the crops to be sure that accurate results are secured. These fields include tests under the livestock and grain systems of farming, in the former, manure being applied, and in the latter, crop residues being utilized in place of the manure. Other fertilizing materials tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure has been applied in all cases at the rate of 8 tons per acre once in a four-year rotation. Limestone has been used in sufficient amounts to neutralize the acidity of the soil

and supply 2 tons additional. Rock phosphate is applied at the rate of 2,000 pounds per acre once in the rotation. Acid phosphate is used at the rate of 200 pounds per acre annually and a standard 2-8-2 complete commercial fertilizer has been used at the rate of 300 pounds per acre annually. These plots are 156 feet 6 inches by 28 feet in size, representing, therefore, one-tenth of an acre.

THE HUDSON FIELD

The Hudson field was laid out in 1917 on the Tama silt loam near Hudson in Black Hawk county. The results obtained on this field for 1918, 1919 and 1920 are given in table XI. Crop yields were not secured in 1921, owing to oversight on the part of the cooperator.

The results given in this table indicate quite definitely the beneficial effects of manure, lime and phosphorus fertilizers on the Tama silt loam. This is the same soil type which occurs on the major portion of the upland in Marshall county and conditions are so similar in the two counties that the conclusions from the experiment should be applicable to the same soil conditions in Marshall county. Manure seems to be of particular value on this soil for corn and oats and it is particularly interesting to note the beneficial effect of lime when applied to this soil along with manure. Rock phosphate, acid phosphate and a complete commercial fertilizer all brought about beneficial effects on these crops, the relative value of the three materials being somewhat different on the different crops and somewhat different on the same crop in different seasons. It is quite probable that phosphorus fertilizers may be used on this soil in many cases at the present time with beneficial effects and, while it is not possible to choose between the various phosphorus carriers from the results at hand, more complete data secured over a long period of years will undoubtedly show which phosphorus carrier is of the most economic value. The results serve to emphasize the recommendation that farmers test the use of these materials on small areas on their own farms and, if they prove of value, they may apply the same material to larger areas.

JESUP FIELD

The field experiment on the Carrington loam near Jesup in Black Hawk county was started in 1917 and the results are available for 1918, 1919, 1920 and 1921 on Series II and for 1918, 1919 and 1920 on Series I. In the latter series, the plots were in pasture during the season 1921 and hence no data is available. Both these experiments were carried out in the usual way and include thirteen plots in each series. Only the results of the livestock system

TABLE XI. FIELD EXERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY, HUDSON FIELD

Plot No.	Treatment	Corn bu. per acre 1918	Oats bu. per acre 1919	Corn bu. per acre 1920
1	Check	45.8	47.6	53.2
2	Manure	49.3	54.7	62.8
3	Manure+lime	54.4	59.2	67.4
4	Manure+lime+rock phosphate	56.5	64.9	73.3
5	Manure+lime+acid phosphate	57.4	62.2	73.3
6	Manure+lime+complete commercial fertilizer	58.5	57.5	72.4

plots are given, however, as the crop residues have not been sufficiently utilized as yet to exert any effect on the soil. The results of this experiment cannot be interpreted too broadly as yet, owing to the fact that there are some variations in yields such as are commonly obtained in the field. They do serve to indicate, however, the effects of fertilizer treatment on this particular soil and the conclusions drawn from them will undoubtedly prove applicable to Marshall county.

The results of this experiment are given in table XII and there is evidence of a beneficial effect of the application of manure on at least two of the crops. The yield on the check plot in 1919 was abnormal and hence conclusions cannot be drawn from the results secured. Lime in addition to manure had little effect on the corn, but did increase the clover and timothy. Rock phosphate showed a considerable effect on the corn and its effect was quite definite on the clover in 1920. There was little influence of this material, however, on the oats. Acid phosphate increased all three crops, showing the largest effect on the oats and on the timothy and clover. The complete commercial fertilizer showed the largest effect of all the treatments on the corn and on the oats, but had somewhat less effect on the clover and timothy than did the acid phosphate. Apparently manure and lime may be used on the Carrington loam with profit and there is evidence that phosphorus fertilizers may also prove profitable. The relative value of the different phosphorus carriers cannot be determined from these data. Further tests are necessary, but the evidence given serves to emphasize the need of testing phosphorus carriers on this soil in order to determine their value under special soil conditions.

The results obtained on Series II on the Jesup field are given in table XIII.

The results obtained in this experiment very largely confirm those obtained in Series I on the same soil. The application of manure brought about a rather definite increase in the yields of clover in 1919, clover and timothy in 1920 and corn in 1921. The application of lime showed some effect on the various crops grown, being particularly evidenced on the clover in 1920. The yield on the manure plot in 1919 was somewhat abnormal and hence the effect of lime does not show up in this particular season. Rather large influence was shown on the oats and some effect appeared also in the case of the corn. The application of rock phosphate showed little effect on any of the crops, but acid phosphate showed up very distinctly in the case of the clover in 1919. The complete commercial fertilizer likewise showed a distinct effect on the clover, both in 1919 and in 1920, the influence on the corn in 1921 being, however, very little different from that of the other phosphorus carriers.

TABLE XII. FIELD EXPERIMENT, CARRINGTON LOAM, BLACK HAWK COUNTY, JESUP FIELD, SERIES I

Plot No.	Treatment	Corn bu. per acre 1918	Oats bu. per acre 1919	Clover & timothy tons per acre 1920
1	Check	34.8	....	0.70
2	Manure	39.0	43.9	0.90
3	Manure+lime	40.4	43.5	1.10
4	Manure+lime+rock phosphate	52.7	40.5	1.57
5	Manure+lime+acid phosphate	50.3	52.4	2.20
6	Manure+lime+complete commercial fertilizer	59.2	58.9	2.00

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

Plot No.	Treatment	Oats bu. per acre 1918	Clover tons per acre 1919	Tim'thy & clover tons per acre 1920	Corn bu. per acre 1921
1	Check	71.9	1.17	0.50	58.7
2	Manure	71.6	2.08	0.85	72.8
3	Manure+lime	83.1	1.92	1.20	77.6
4	Manure+lime+rock phosphate	81.8	1.86	1.15	78.1
5	Manure+lime+acid phosphate	76.1	2.22	1.12	75.5
6	Manure+lime+complete commercial fertilizer	77.2	2.80	1.25	78.7

Apparently the application of manure is of particular value on the Carrington loam and the use of lime when the soil is acid may bring about a distinct effect on the legumes of the rotation. Phosphorus carriers may prove of value on this soil and their effects may appear on any of the crops grown, showing up more definitely on clover, particularly in the case of acid phosphate. The suggestion that farmers test the use of various phosphorus materials on this particular soil type is emphasized by these results and it is apparently quite desirable that they determine by special tests what phosphorus carrier should be used on their particular soils.

These field experiments as a whole serve to confirm the results obtained in the greenhouse tests, showing the value of manure and lime on the Tama silt loam and the Carrington loam, the two main types in the county, and the possibility of the value of phosphorus fertilizers on these soils.

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

Field experiments have just been started on some of the main soil types of Marshall county and there is no data available as yet from these tests showing the value of various fertilizer treatments. The field experiments from Black Hawk county which are included in this report, however, are located on the same types which are most extensive in Marshall county and hence the results of those experiments may be considered to indicate rather definitely the results which may be secured in Marshall county. After the experiments in this county have been under way for a period of years, they will be published in a supplementary report and it will then be possible to draw more definite conclusions regarding the most economic treatments for the various soil types. For the present, the suggestions which are made as to desirable treatments are based only on the results of the laboratory and greenhouse tests and on the field tests of the same soil types in Black Hawk county. However, no definite recommendations are made in this report which have not been tested to some extent by individual farmers and have been proved valuable, therefore, by practical experience.

It should be emphasized that individual farmers may carry out tests on their own farms with certain fertilizing materials and determine their value. In

this way the farmer may secure very definite information regarding the desirability of using the various fertilizing materials on their own soils. Furthermore, the information which is secured in this way is of considerable value to a solution of the problem of fertilization of the same soil types elsewhere. This suggestion is often made and many farmers are now conducting tests on a small scale which are giving them results of much interest and value. These tests are not complicated and may very readily be planned and carried out. The Soils Section of the Iowa Agricultural Experiment Station is ready to aid and assist farmers who wish to carry out tests of various materials. Until the field experiments now under way are more complete and the results conclusive, the best suggestion which can be made is the testing of various materials on small areas. The additional suggestions which are given in the following pages are only those which are of value as shown by practical experience and that may be put into operation under any farm conditions.

LIMING

The soils of Marshall county are very largely acid in reaction and, therefore, in need of lime. None of the major soil types in the county contain any quantity of bases or inorganic carbon, as will be seen from a consideration of the tables given earlier in the report. In fact, there is only one type in the county which is high in inorganic carbon content and this type, the Lindley loam, is of very minor importance. Three other soils do not give an acid reaction in the surface soil, but the content of basic material is so small that the amount present will soon be exhausted and the soils will soon react acid. Two of the soil types which react acid in the surface soil give a basic reaction in the subsurface and subsoil, but in these cases, also, the amount of lime present is so small that the soils will soon be in need of limestone. These are also minor types in the county.

It is apparent that the needs of the surface soils may be taken to show the lime requirement of the soils and that little attention need be paid to the subsoil conditions. In fact, the presence of small amounts of lime in the subsoil is of little significance, inasmuch as lime rarely moves upward in the soil, but tends rather to be washed out quite rapidly in the drainage water. The results of the analyses certainly indicate that in general the soils of the county are in need of lime, and tests should be made at regular intervals in all cases if the soil reaction is to be kept satisfactory for crop growth.

It should be understood that the results given in the tables are not applicable to all areas of the various soil types, but are merely indicative of the needs of the individual soil types. Soils vary widely in lime requirement, and even the same soil type may show a quite variable need for lime. Hence the figures given should not be interpreted too broadly. Before lime is applied to any soil, a test should be made of the particular soil in order that the application of lime may be sufficient and in order to avoid the addition of too small an amount. Farmers may test their own soils for acidity or lime requirements, or they may send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. By doing this they will insure the use of the proper amount of lime and they will also insure the best

reaction in the soil for the growth of general farm crops, particularly legumes. Clover and alfalfa are especially sensitive to lack of lime in the soil and will not make a satisfactory growth on acid soils and in many cases increases in other crops are secured when lime is applied to acid soils.

The results obtained on the soils of Marshall county indicate, therefore, that all the soils of the county should be tested for acidity and lime applied as shown to be necessary, if the best crop growth is to be secured. When soils are cultivated there is a continual loss of lime thru utilization by crops and particularly thru leaching or washing away in the drainage water. If the soil is well drained, as is absolutely necessary, of course, if the soil conditions are the most satisfactory for crop growth, the loss of lime by drainage may be considerable. The texture of the soil is also of significance and light soils lose their lime content much more rapidly than heavier textured types. In all cases, however, where crops are grown, lime gradually disappears and hence one test for acidity, one application of lime to a soil, will not be sufficient for all time. Tests must be made at regular intervals and lime applied as needed, if the soils are to be kept in the best reaction for crop growth. It is suggested that probably a test once in a four-year rotation is sufficient and that lime should be applied preceding the clover crop of the regular four-year rotation. This is due to the fact that the clover or any other legume in the rotation will be benefited to the largest extent by the application of lime. Other crops of the rotation may show an indirect benefit from the use of lime, but the effect on corn, oats and other small grains is usually of less importance than the effect on clover or alfalfa.

Many tests under farm conditions have shown the benefits to be derived from liming. The experiments referred to in the preceding pages emphasize the importance of lime on acid soils if legume crops are to be grown satisfactorily. It is quite evident from much practical experience and from considerable experimental data, that liming is a profitable practice, even if the clover crop alone is considered. When the secondary effects of lime on corn and small grains are taken into account, the economy of adding lime to acid soils is quite apparent. The value of the increased crop growth more than offsets the expense of the application. The farmers of Marshall county may be assured that applications of lime to their soils, when acid, will give them profitable returns. They should see to it that their soils are tested, especially if legumes are to be grown, if they hope to secure satisfactory yields. Further recommendations regarding the use of lime on soils, losses by leaching and other information connected with liming are given in Bulletin 151 of the Iowa Agricultural Experiment Station. The list of the companies from which the material may be secured and the cost of the same are given in Circular 58.

MANURING

Many of the soils of Marshall county are rather poorly supplied with organic matter and there are few instances where additions would not be of value at the present time. Manuring is perhaps the most important farm practice for the soils of this county and the results secured from the use of manure are

very definite. There is no other fertilizing material which has given anything like as large effects on crop growth as has farm manure. The practical experience of many farmers in the county and the experiments reported in the preceding pages are in entire agreement in showing the large crop increases secured from the use of farm manure. On those soils which are particularly low in organic matter, as shown by the analyses, manure gives especially large returns. Such effects are noted on the sandy soils in the county or the lighter textured types, but even on those types which seem to be fairly well supplied with organic matter, crop yields are increased to a large extent by the use of farm manure. The Tama silt loam, for example, is not particularly deficient in organic matter; in fact, it shows a content which is almost as high as any type in the county and yet the application of manure has quite consistently given increased crop yields. Every farmer in Marshall county should see to it that the manure produced on his farm is carefully preserved and applied to the soil, if satisfactory crop growth is to be secured and the soils kept permanently fertile.

Manure benefits soils because of its action on the chemical, physical and bacteriological conditions. It adds plant food constituents to the soil, returning, as it does, a large part of the plant food which has been removed from the soil by crops which have been utilized for feed. Hence manure will lengthen the life of the soil or, in other words, prolong the time until any of the essential plant food constituents become deficient. Manure improves the physical condition of soils, whether heavy or light. It opens up heavy soils and makes them less impervious and better aerated and permits of the removal of excessive moisture. It makes light soils more retentive of moisture, less open and porous and less subject to losses by leaching. By its physical effect on soils, manure exerts a secondary chemical effect in that more available plant food is produced and crops are better supplied with necessary food constituents. Applications of manure to the soil mean also the addition of enormous numbers of bacteria which are contained in the manure, and these bacteria have a distinctly beneficial effect, due to their ability to transform unavailable plant food into an available form. The improved physical conditions stimulate bacterial action, and greater bacterial action means more plant food and hence better crop growth. There are undoubtedly many instances where the bacterial effects of manure are of major importance. On soils which are rather well supplied with organic matter, it seems probable that the bacterial effects of manure are of much significance. Perhaps this is the reason for the very distinct effect in the case of the Tama silt loam. On most soil types, however, when increased crop yields are secured from the use of manure it is probably because of a combination of bacterial, chemical and physical effects. There are, of course, instances where the actual addition of plant food would be of the greatest importance, but in general for Marshall county soils, the effect of manure is undoubtedly attributable to improved physical conditions for plant growth and a better production of available plant food.

The beneficial effect of manure is shown in the case of general farm crops and it is usually conceded that no other fertilizing materials will prove of as large value if manure is not applied with them. The fertilization of the soils

of the county should, therefore, begin with the use of manure and, if other fertilizers are employed, they should be used in addition to manure if economic results are to be secured. This statement applies, of course, only to livestock farming conditions and if manure is not available on the farm, other sources of organic matter must be employed, as will be noted later.

The value of manure as a fertilizer for general farm crops is so large that the importance of preserving the manure produced on the farm to permit of its exerting the largest possible effects is quite evident. If manure is stored in loose heaps and exposed to the weather and to the leaching actions of rains, it may lose from 70 to 90 percent of its valuable material. Under such conditions the application of manure will not bring about the large effects on crop growth which may be secured from the properly stored material. Hence, the improper storage of manure may lead to actual economic loss on the farm. The farmer who is not preserving the valuable portion of the manure produced on his farm is decreasing his crop yields and hence reducing his income. There are various ways in which manure may be stored to prevent the loss of valuable material and no one method can be suggested for all conditions. It may be stored in a covered yard or pit and protected from the weather, or it may be composted, but whatever method is used, it is particularly important that the manure be kept moist and compact and protected from the weather.

It may be possible in some cases to apply the manure as produced, to the soil. In such cases there is, of course, no storage problem. There are, however, many instances where such a method of application is not possible or desirable and then some method of storage must be selected which will permit of the securing of the largest possible beneficial effects from the application of the material. It is estimated that when manure is applied as produced, or when it is carefully stored before application, it may return to the land 75 to 80 percent of the plant food which has been removed from the soil by the crops grown, and it is up to the farmer to see to it that none of the valuable material contained in the manure is allowed to escape from the farm.

The production of manure on the average livestock farm is unfortunately quite insufficient in most cases to permit any large application to all the soils of the farm. The usual application is 8 to 10 tons per acre once in a four-year rotation. Larger applications than this are sometimes made on very light textured soils for certain crops, but for general farm crops it is usually not desirable to apply more than 16 to 20 tons per acre. Only in cases where truck crops are to be grown should larger applications of manure than this be applied and even here extremely large applications are not always desirable or necessary, and it should be remembered that if very large applications are made to one field the remainder of the farm may suffer, so it is well to take care that applications of manure are made at regular intervals and in reasonable amounts, if the growth of general farm crops is to be satisfactory and all the soils of the farm are to remain productive.

Even on the livestock farm there is not sufficient manure to maintain the supply of organic matter and nitrogen in the soil and on the grain farm, of course, some other material must be utilized in place of farm manure. In both instances, green manuring is a practice which should be followed, either as a

supplement to manuring or as a substitute for that practice. Leguminous crops are the most desirable for use as green manures because of the fact that when well inoculated they possess the ability to take up nitrogen from the atmosphere and fix it in the soil, where it may be utilized by subsequent crops. Such crops not only keep up the supply of organic matter, but they also act as nitrogenous fertilizers. Nonlegumes, on the other hand, do not increase the nitrogen content of the soil, but merely build it up in organic matter. When organic matter is low in soils, however, the nitrogen content is usually low also and hence there are few instances when leguminous crops would not be more desirable for use as green manures than non-legumes. There are many legumes available for use under a wide variety of conditions, and some one may be chosen which will fit in with almost any rotation. Green manuring undoubtedly may be practiced profitably in some cases in Marshall county where the supply of farm manure is limited and the soils are particularly deficient in organic matter. The practice, however, should not be followed blindly or carelessly because of the fact that undesirable effects may result if the conditions are not such that rapid decomposition will follow the plowing under of the crop. When soils are dry, for example, green manuring should not be practiced, as there may be a detrimental interference with the moisture conditions. Advice regarding green manuring under special soil conditions will be given by the Soils Section upon request.

The proper utilization of all crop residues, such as straw and stover, is very important if the organic matter content of the soils of the county is to be kept up. These materials are frequently burned or otherwise destroyed and when this occurs there is a large loss of valuable material and the farmer is actually throwing away valuable fertility constituents. Such materials may be used on the livestock farm for feed or bedding and returned to the soil with the manure. On the grain farm they may be applied directly to the soil, or they may be stored under proper conditions and allowed to decompose partially before they are applied. On the grain farm the return of all crop residues is of particular significance, owing to the lack of manure, but these materials should be quite as carefully used on the livestock farm in order to supplement the manure. Crop residues not only supply organic matter to the soil but they also add plant food constituents and hence actually lengthen the life of the soil. Many times crop residues have been found to exert distinctly beneficial effects on crop growth and they should be considered as valuable supplements to manure and green manures if soil conditions are to be kept most satisfactory for crop growth.

THE USE OF COMMERCIAL FERTILIZERS

The results of the analyses of the soils of Marshall county which have been given earlier in this report show quite distinctly that phosphorus is not present in any considerable amounts in any of the types and in most cases the amount present is so low that phosphorus will certainly be needed on these soils in the near future if, indeed, phosphorus fertilizers would not prove profitable for use at the present time.

There is always a possibility, where the total supply of phosphorus is as low as is the case in some of these soils, that the amount of available phosphorus present will be insufficient to permit of the most satisfactory crop growth. The greenhouse experiments and the field experiments on two of the important soil types in an adjacent county indicate that phosphorus fertilizers may be used at the present time with value, at least in some cases. The results of the greenhouse experiments are, of course, merely indicative of what may occur in the field, but it is usually true that the indications from the greenhouse tests are borne out by later field results. The results of the field experiments which are reported on two soil types from Black Hawk county are undoubtedly applicable to the same soil conditions in Marshall county, and it may safely be concluded that phosphorus will be needed on these soils in the near future and may show profitable returns even at the present time.

It is not possible, furthermore, from the experiments which have been discussed to draw definite conclusions regarding the particular phosphorus fertilizer which should be used in any case. Acid phosphate or rock phosphate may be employed, and the former frequently gives the larger returns. In other cases, however, rock phosphate proves of more economic value. Acid phosphate is more expensive than rock phosphate, but it contains phosphorus in an available form and hence this element is more readily utilizable by crops. On the other hand, rock phosphate has a low rate of availability and considerably larger applications must be made. A choice between these two phosphorus carriers must depend, therefore, upon the cost of the actual application, the value of the crop increases secured from the use of the material and upon the results secured for at least one rotation. It is necessary to take the yields for at least four years in order that opportunity may be given for the utilization of the rock phosphate to the best advantage. This material is applied but once in the rotation, while acid phosphate is added annually. The experiments which have been begun in Marshall county and those which are under way in Black Hawk county on the same soil types will yield definite information along this line at a later date. The results of these field experiments, when they are more complete, will be published in later reports. At the present time sufficient results have not been secured to permit of definite conclusions. It can only be recommended, therefore, that farmers test these two phosphorus fertilizers on their own soils and determine for their own conditions which material will yield the larger value. It is not a difficult matter to test these materials on the farm and directions which may be readily followed in conducting such tests are given in Circular 51 of the Iowa Agricultural Experiment Station. If one of these fertilizers shows profit according to a test on a small area, then the same material may be used on a large area with the assurance of profit. Farmers in Marshall county who are interested in increasing their crop yields and building their soils up in fertility, are urged to test the use of phosphorus on their own farms and determine the value of phosphorus fertilizers for their particular conditions.

Some of the soil types in Marshall county are apparently well supplied with nitrogen, but in other cases the amount of this element present in the soil is too low for the most satisfactory crop growth. Even on the better supplied

types, however, the amount of nitrogen present is insufficient for the continuous growth of satisfactory crops over a long period of years. In planning systems of permanent fertility for the soils of the county, the maintenance of the supply of nitrogen in the soil should not be disregarded, even on those types which are apparently well supplied. There is a continual removal of nitrogen from soils by cropping and, on the better types which are well drained and in the best physical condition for crop growth, there may be a considerable removal in the drainage water. It is essential, therefore, that some nitrogenous material be used on all the soils of the county in order to keep up the supply.

The proper preservation and application of farm manure will insure the return of a large portion of the nitrogen removed from the soil by the crops grown and may keep the loss of this constituent down to a small amount. On the livestock farm, therefore, the maintenance of the nitrogen supply is much more readily accomplished than on the grain farm because of the manure which is available for use. It is impossible, however, to keep up the supply of nitrogen by the use of farm manure alone, even on the livestock farm, owing to the fact that the amount produced on the average farm is insufficient to provide for all the soils of the farm. Hence this material must be supplemented on the livestock farm and something must be substituted for it on the grain farm. Leguminous green manures are the cheapest and the most efficient nitrogenous fertilizers which may be employed. Every rotation should contain a legume and if this legume is inoculated as it should be, there may be an addition of nitrogen to the soil, owing to the fact that the inoculated legume draws a large part of its nitrogen from the atmosphere. When the leguminous crop is removed from the soil, there is, of course, in most cases, no addition of nitrogen, and if the soil is to be built up in nitrogen, a part or all of the legume crop must be turned under as a green manure in order to increase the nitrogen content of the soil. The removal of the legume crop would probably not reduce the nitrogen content of the soil to any extent, but if it is to really serve as a nitrogenous fertilizer, it must be handled as a green manure crop. If the seed only of red clover is removed and the remainder of the crop is turned under in the soil, the crop may serve to bring about very desirable effects as a green manure and increase to a considerable extent the nitrogen content. Legumes may also be used in the rotation as catch crops, in which case they may supply considerable nitrogen as well as organic matter to the soil. There are undoubtedly some cases in Marshall county where the utilization of legumes as green manures would be desirable from the standpoint of building up the supply of nitrogen. The proper utilization of crop residues on all farms aids materially in cutting down the losses of nitrogen and they are a valuable supplement to farm manure and green manures.

Commercial nitrogenous fertilizers may be utilized in small amounts as top dressings to encourage the early growth of certain crops, but their use for general farm crops on the soils of the county cannot be recommended at the present time. If they prove of value on small areas for certain crops, they may be used without fear of injuring the soil, but leguminous crops as green manures are undoubtedly a cheaper and more generally satisfactory source of nitrogen.

Earlier tests of the soils of the state have shown a large amount of potassium in all cases and there is no doubt but that the soils of Marshall county are in general very well supplied with this element. There is enough present to provide for crop production for many hundreds of years, provided it is made available sufficiently rapidly. It seems unlikely, therefore, that potassium fertilizers would prove of value on the soils of the county. They might be used in small amounts as top dressings to stimulate the early growth of some crops, but their use for general farm crops could not be recommended now. If any farmers are interested and wish to test these materials on small areas they may readily determine whether or not the materials will give profitable returns. If they show value on small areas they may be used on larger areas without any injury to the soil. It should be emphasized that it is very important to keep the physical condition of the soils satisfactory for the production of available plant food in order that available potassium may be supplied in sufficient amounts to permit of the best crop growth. It is particularly important that the soils be well drained and cultivated and that they be well supplied with organic matter. When these conditions are observed there should be a sufficient production of available potassium from the store already present in the soil so that additional applications will not prove necessary.

Experimental work now under way includes the testing of certain complete commercial fertilizers and if farmers are interested in any particular brands, they may test them on small areas on their own farms and determine their value. For the present, no definite recommendations regarding the use of these materials can be made. They have not yet shown economic returns in comparison with phosphorus carriers according to the field data which is available and it is considered extremely unlikely that they will prove as economic as phosphorus fertilizers, owing to the fact that the nitrogen which they contain may be more cheaply supplied by the use of legumes, and the potassium present in them is not needed. In the course of the next few years results will be available which will show definitely the relative value of complete fertilizers in comparison with acid phosphate and rock phosphate, but for the present they cannot be recommended for general farm use in Marshall county. They should certainly not be used on large areas until tests have been carried out on a small scale and their value definitely proved for the particular conditions and especially their superior value over phosphorus carriers. There is no objection to the use of complete commercial fertilizers as far as the soil is concerned and the chief factor to be considered is their economic value in comparison with phosphorus fertilizers.

DRAINAGE

Marshall county is quite adequately drained in most parts, as has already been noted, and the drainage map which is given earlier in this report gives a rather definite idea of the drainage system of the county. There are very few cases, therefore, where artificial drainage is necessary, but in some instances the installation of tile would be of value in increasing crop production.

The Clyde silty clay loam and the Bremer silty clay loam of the upland and terrace are poorly drained and the Wabash silty clay loam of the bottom

is likewise poorly drained. This type is also subject to overflow and the same is true of the Wabash loam and the silt loam. In the case of all these types, proper drainage would be of value in increasing their productivity. No other soil treatment will prove of value if the soil is poorly drained and the first treatment needed to insure satisfactory crop production is to take care of the drainage of the soil. Even tho tiling may be somewhat expensive, the expense is more than warranted by the returns which are secured in the way of better crop growth. Besides the soil types mentioned, there may be areas in the county of certain other types which would be benefited by the installation of tile. In general it may be said that any of the soils of Marshall county which are poorly drained should be tiled out if the best crop yields are to be secured.

THE ROTATION OF CROPS

It is a well known fact that the natural fertility of soils is rather rapidly reduced by the continuous growing of any one crop. In fact, continuous cropping will bring about a reduction of fertility in the soil much more rapidly than when a rotation is used. Even if the particular crop which is grown continuously is of considerable value, the income from the land over a period of years will be greater when a rotation is followed. Apparently the use of some rotation is absolutely necessary if the soil is to be kept permanently in a fertile condition.

Just what rotation should be followed must be determined by the local conditions and no one rotation can be recommended as desirable under all circumstances. It should be emphasized, however, that any rotation should contain a legume and likewise the most profitable crops of the region. No rotation experiments have been carried out in Marshall county. The following are given, however, as examples of rotations which are of the most common use in the state and have proved quite satisfactory.

1. FOUR OR FIVE-YEAR ROTATION

First Year —Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation).
Second Year—Corn.
Third Year —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.)

2. FOUR-YEAR ROTATION WITH ALFALFA

First Year —Corn.
Second Year—Oats.
Third Year —Clover.
Fourth Year—Wheat.
Fifth Year —Alfalfa. (This crop may remain on the land five years, and the fields should then be used for the four-year rotation outlined above.)

3. THREE-YEAR ROTATION

First Year —Corn.
Second Year—Oats or wheat (with clover seeded in the grain).
Third Year —Clover. (Only the grain and clover seed should be sold; in grain farming 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.)

Fig. 6. Serious washing often occurs in draws in the Carrington loam in Marshall county.

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 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 the 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 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 Marshall county erosion occurs to a considerable extent in the areas of Shelby loam, Clinton silt loam and Lindley loam. In some instances serious washing has occurred in some of the other soil types, and wherever any removal of surface soil thru this destructive actions occurs, some means of prevention or control should be adopted.

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

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle to 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 upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru, but holding the fine soil.

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. 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 drainage-ways and may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottom-lands, 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 problems 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 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 4 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 4 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 2 or 3 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 supplied 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, but 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 upstream 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 results 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 proved 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 drainageways 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 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. It is, however, rather expensive. Then, too, it may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to the 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 the 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 or Adams dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

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

Straightening and Tiling. The straightening of the larger streams in bottomland areas may be accomplished in 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 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 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 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 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 slope, or at an angle to it, is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proved 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 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 may be thereby 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 MARSHALL COUNTY*

There are fifteen soil types in Marshall county and an area of muck, making a total of sixteen separate soil areas. These are divided into four large groups, according to their origin and location, and these groups are known as drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are five drift soils in the county, which belong in the Carrington, Shelby, Lindley and Clyde series, and together they cover 19.8 percent of the total area of the county.

CARRINGTON LOAM (1)

The Carrington loam is the most extensive drift soil, covering 10.2 percent of the total area. It occurs mainly in the western part of the county, in an irregular shaped area extending from the northern boundary, where it is over two miles wide, to a narrow point near the southern boundary. It takes up practically half of Liberty and Minerva townships and a large part of State Center township. It also occurs in narrow areas along the streams and intermittent drainageways in the northeastern part of the county. In this part of the county it is found chiefly along Chicken creek, Asher creek, Little Asher creek, Burnett creek and Devil's Run, and separates the loessial upland of the Tama series from the Wabash bottoms. In its extensive area in the western part of the county it occurs almost continuously, being dotted with small areas of the Clyde silty clay loam and cut in some instances by areas of Wabash loam and Wabash silt loam along the streams.

The surface soil of the Carrington loam is a dark brown heavy loam, 8 to 10 inches in depth. In the flatter areas it is almost black in color and frequently extends to greater depths. The subsoil is a brownish-yellow heavy loam to clay loam, somewhat gritty in texture. There is no sharp line of division between the surface soil and the subsoil, the former gradually passing into the lighter-colored, heavier-textured subsoil. Boulders occur on the sur-

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

Fig. 7. The Carrington loam topography is very much like the gently rolling Tama.

face and thru the soil section, but they are not present in large enough numbers to interfere seriously with cultivation.

In topography the Carrington loam in the western part of the county is gently rolling to rolling. In the narrow areas northeast of the Iowa river the topography is moderately sloping, and the soil in these areas is modified to some extent by the loessial material from the Tama uplands. The type is generally well drained and is not in need of tiling. In some areas, particularly in the northeastern part of the county, erosion has occurred to some extent and control measures are necessary.

About 95 percent of this type is now under cultivation, the rest being in permanent pasture and farmsteads. Corn is the most important crop, about one-third of the type being used for its production. Average yields of about 45 bushels per acre are obtained and in many cases where the soil has been carefully treated, much higher yields than this are secured. The major portion of the corn produced is fed to hogs and the same is true of oats, which is the second crop in acreage. Yields of oats range from 35 to 40 bushels on the average. Clover and timothy do well and yield 1½ to 2½ tons per acre. Wheat, barley and rye are relatively unimportant crops on this type. Alfalfa is grown only in an experimental way. A few potatoes are produced for home consumption and some sorghum has been grown.

The Carrington loam is a relatively fertile soil, but it would be benefited considerably by better soil treatments. It is acid and should be limed if satisfactory crops, particularly of legumes, are to be secured. It is not particularly high in organic carbon or nitrogen and applications of farm manure have been found to bring about large increases in crop growth. The field experiments and the greenhouse tests, described earlier in this report, and much farm experience have shown rather considerable effects from the use of farm manure on general farm crops. If farm manure is not available in sufficient amounts, leguminous green manures would improve the nitrogen

and organic matter content of this soil and make it more productive. The phosphorus supply is rather low and applications of phosphorus fertilizers would undoubtedly prove of value in some cases. This is also indicated in the field and greenhouse tests. Just which particular phosphorus carrier should be used must be determined by special tests. Where the soil has been subject to erosion, methods for the control and prevention of this destructive action should be taken. With these treatments as suggested, the Carrington loam may be made more productive than it is at present and large crop yields may be insured for future years.

SHELBY LOAM (79)

The Shelby loam is a minor soil type in the county, covering 7.0 percent of the total area. It occurs in narrow areas in various parts of the county along many of the streams. It is found principally in the southern half of the county, altho there is a rather extensive area in Marion township along Rock creek and Nicholson creek. In most cases it separates the Tama silt loam of the upland from the Wabash silt loam of the bottoms, altho there are many areas where it occupies intermittent drainageways completely and no bottomland is found.

The surface soil of the Shelby loam is a medium brown to dark brown silty loam. At a depth of 8 inches, on the average, the soil passes into a yellow gritty, silty clay loam or clay loam. In some instances the subsoil is a stiff, tenacious, reddish-brown clay. Considerable gravel and some boulders occur over the surface of the type and frequently thruout the three-foot section, but not in sufficient numbers to interfere with cultivation.

In topography this soil is rolling, and it is subject to destructive erosion. Gullies 10 to 15 feet in depth are quite common and, unless controlled, these gullies may increase rapidly and extend back into the loess covered uplands.

About 45 percent of the Shelby loam is under cultivation, the remainder being very largely in permanent pasture. The same crops are grown as on the Tama silt loam, but the yields are lower, corn giving 25 to 35 bushels, oats 25 to 30 bushels and clover and timothy 1 to 1½ tons per acre.

The Shelby loam is mainly in need of protection from erosion, if it is to be kept in cultivation and satisfactory crop yields are to be secured. It is acid in reaction and in need of lime, especially if legumes are to be grown. It is relatively low in organic matter and nitrogen, and applications of farm manure have proved of large value. Green manures might be used in place of farm manure in many cases, not only to increase the fertility of the soil, but to aid in preventing its washing away. The phosphorus supply is not high and the soils will need some phosphorus fertilizer in the near future. It is probable, however, that in many instances phosphorus fertilizers will prove of value now.

LINDLEY LOAM (65)

The Lindley loam is a minor type in the county, covering only 1.0 percent of the total area. It occurs entirely in the southwestern part of the county, in association with the Clinton silt loam and the Tama silt loam. It is found along Clear creek, separating the Tama and the Clinton upland soils from the Wabash bottoms.

The surface soil of the Lindley loam is a light brown to light grayish loam and it extends to a depth of 6 inches on the average. At that point it passes

Fig. 8. Rough topography characteristic of the Lindley loam in Marshall county.

into a yellow loam to clay loam subsoil. Gravel occurs both in the surface soil and in the subsoil.

In topography the Lindley loam is rolling to rough, lying on the steep slopes along the drainageways. It is thoroly drained, except in a few instances. It is subject to erosion and destructive washing has prevented its cultivation.

This type was originally forested with oak, elm, sumac and hazel brush and much of it is still in woodlots and permanent pasture. When the topography is favorable for cultivation, oats, corn and clover may be grown successfully. The soil, however, is extremely low in organic matter and nitrogen and applications of farm manure or leguminous green manures are very desirable if satisfactory crop yields are to be secured. It is not acid in reaction and contains a rather large amount of carbonates. The phosphorus supply is not high and phosphorus will be needed in the future, altho it is a question whether any phosphorus fertilizer would prove of value on the type at the present time. It should be protected from washing and in many areas it will probably prove most satisfactory to keep it in pasture.

CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor type in the county, covering only 0.9 percent of the total area. It occurs in several areas on the slopes, between the stream terraces or the first bottoms and the higher silty loessial upland. The largest area is found along Minerva creek two miles west of Albion. Smaller areas are found south and east of Albion and east of Clemons. Other small areas occur along the Iowa river, Honey creek, Asher creek and Minerva creek.

The surface soil of the Carrington fine sandy loam is a dark brown fine sandy loam, 10 to 15 inches in depth. The subsoil is a brownish-yellow to yellow

Fig. 9. Erosion occurs extensively in the Lindley loam.

fine sandy loam, very open and porous in structure. Boulders are scattered over the surface of the soil.

In topography the type is gently rolling to rolling. It is subject to drouth, owing to the open sandy texture of the subsoil. It is not gullied or eroded to any extent and, when properly handled, may be utilized for the growth of general farm crops.

About 85 percent of the type is utilized for crop production at present and corn is the principal crop grown. Average yields of 30 to 35 bushels per acre are secured and these yields may be increased considerably under favorable conditions. Oats are grown to some extent and yield from 30 to 35 bushels per acre.

This soil is acid in reaction and would respond to applications of lime. It is in need of organic matter, and additions of farm manure would prove of large value. Leguminous green manures would also prove of value in many cases, especially where applications of farm manure are necessarily limited. It is low in phosphorus and, for the growth of general farm crops, applications of phosphorus fertilizers would undoubtedly be of value. It is particularly necessary on this type that the organic matter supply be increased in order to protect the crops during periods of drouth.

CLYDE SILTY CLAY LOAM (85)

The Clyde silty clay loam is a very minor soil type in the county, covering only 0.7 percent of the total area. It occurs in small areas, chiefly in the western part of the county. There are a few small areas in the northeastern part of the county and a few areas along Minerva creek, in the center of the county. In general, however, this type is confined to the western part of the

county and is associated with the Carrington loam. It is found in depressions in the upland and in a few areas along intermittent drainage lines.

The surface soil of the Clyde silty clay loam is a black silty clay loam, 15 to 18 inches in depth. This is underlaid by a light gray silty clay loam, mottled with brownish-yellow and rusty brown. The surface soil is plastic and sticky when wet and hard when dry. In the areas surrounded by the Carrington fine sandy loam, the surface texture has been modified by sand washed upon it and sometimes is a light loam to sandy loam.

In topography this type is level to depressed, and it is very poorly drained. Most of it is used for pasture and hay. Where it has been drained, however, it provides excellent farm land and is well adapted to corn, average yields of 50 bushels per acre being secured. Oats do not do well on the soil, as they are apt to lodge before ripening. It is well adapted to grasses, and timothy and red clover grow very satisfactorily when the soil is drained. Yields of hay ordinarily average ½ to 2½ tons per acre.

As has been indicated, this type is in particular need of drainage and, in fact, it cannot be used for the growth of general farm crops until it is thoroly drained. When this is accomplished, satisfactory crop yields may be secured without further treatment. Small applications of farm manure would be of value on newly reclaimed areas in order to stimulate the production of available plant food. The soil is not acid in reaction in all instances, but quite generally becomes so as soon as drainage is established, and, when this occurs, lime will become necessary. The phosphorus supply does not seem to be particularly low, but phosphorus fertilizers will be needed in the future, and may be of value in some instances at the present time.

LOESS SOILS

There are four loess types in the county, which are classed in the Tama, Muscatine, Clinton and Knox series. Almost three-fourths of the total area of the county, 67.7 percent, is covered by these types.

TAMA SILT LOAM (120)

The Tama silt loam is by far the most important soil type in the county, covering 59.4 percent of the total area. It occurs in extensive areas over the uplands in all parts of the county, except along the western boundary where the uplands are covered with Carrington loam.

The surface soil of this type is a dark brown, moderately heavy silt loam, 10 to 12 inches in depth. It grades thru a layer of brown heavy silt loam, about four inches thick, into a brownish-yellow silty clay loam, the color becoming lighter at the lower depths. The color of the subsoil is usually uniform, altho occasionally there is some mottling with light gray and some streaks of rusty iron stains. The depth of the surface soil is somewhat variable. In the flatter areas it is 15 to 18 inches deep, while on the more rolling portions and along gullies it is only 6 to 8 inches in depth, and occasionally the brownish-yellow subsoil is exposed. Narrow strips of colluvial material along some of the intermittent drainageways are included within this type. Where

Fig. 10. Typical Tama silt loam topography in Marshall county.

it joins the Clinton silt loam, the surface soil is somewhat lighter in color and the subsoil has some characteristics similar to those of the Clinton. It is difficult to draw a sharp boundary line between these two types.

In topography the Tama silt loam is generally rolling to steeply rolling. Only in the northeastern part of the area does the type become more level. Even here it is usually gently rolling. The soil is well drained and tiling is not necessary. Some washing occurs where the slopes are steep, but there is no extensive action of erosion.

About 95 percent of the type is now under cultivation. At least one-half of this is devoted to corn, the remainder being utilized for growing oats, clover and timothy and some wheat. Corn gives average yields of 45 to 60 bushels per acre and, under favorable conditions, much larger yields than this may be secured. Oats yield at the rate of 35 to 50 bushels per acre. Clover and timothy are the principal hay crops and average yields of 1½ to 2½ tons per acre are secured. Wheat is grown to some extent. Millet, sorghum, barley and rye are also produced on small areas. Alfalfa is grown in a few instances and will undoubtedly prove a profitable crop when more is learned regarding its needs and the conditions under which it will prove successful.

The Tama silt loam is a rather fertile soil and crop yields are generally very satisfactory. It is slightly acid in reaction, however, and should be tested for acidity and lime applied as necessary, if satisfactory crops of legumes are to be secured. Applications of farm manure would be of use in many instances and applications of phosphorus fertilizers might prove of value. The results from the field experiments and greenhouse tests given earlier in this report show very distinctly the value of lime and manure when applied to this soil, and also indicate possibilities of value from the use of phosphorus fertilizers. Tests on individual farms with the use of these latter materials are very desirable and in this way it should be possible to select the particular phosphorus fertilizer which should be used.

MUSCATINE SILT LOAM (30)

The Muscatine silt loam is the second largest loess soil in the county, covering, however, only a comparatively small area, 4.9 percent of the total. It occurs in rather extensive areas in the north central portion of the county and is also found in a considerable number of smaller areas in the southern part of the county. The most extensive individual area is north of Albion, extending for a distance of over four miles. It is found in association with the Tama silt loam of the upland, occupying the high, slightly undulating to flat areas of the upland.

It occurs in two distinct phases in the county. The more extensive, which is somewhat similar to the Grundy series, is found north of the Iowa river. Here it is a black heavy silt loam, grading at about 12 inches into a black silty clay loam. This in turn passes into a light gray silty clay mottled with yellow and yellowish-brown. This change usually occurs at about 20 inches. Below 40 inches the subsoil becomes lighter in texture and light gray in color. The entire subsoil is granular in structure and very compact. When dry, it is hard and when wet it is inclined to be plastic. South and west of the Iowa river the areas of this soil are more typical of the Muscatine series. Here the soil is a black smooth silt loam, 15 inches in depth, with a heavy black silt loam subsurface, 15 to 24 inches in depth. Below this the subsoil is a gray silty clay mottled with yellow and brownish-yellow.

In topography the Muscatine silt loam is slightly undulating to level and in wet seasons drainage is not entirely satisfactory. Under normal conditions the type is fairly well drained.

Practically all of the soil is under cultivation and the crops grown are very much the same as on the Tama silt loam. Corn is the most important crop, with oats second, and clover and timothy and a few other crops are of minor importance. The yields of all these crops are very much the same as on the surrounding areas of the Tama silt loam.

The soil is acid in reaction and in need of lime. It will respond to applications of farm manure in much the same way that the Tama silt loam responds. Phosphorus fertilizers will probably prove of value in many instances. With these treatments no difficulty should be experienced in securing satisfactory crop yields and keeping the soil highly productive. It should be emphasized that in some instances tile might be installed with value where the drainage is not quite adequate.

CLINTON SILT LOAM (80)

The Clinton silt loam is a minor type in the county, covering 2.9 percent of the total area. It occurs chiefly south of Marshalltown along Temple creek and in the southwestern part of the county in isolated areas along the bluffs of the Iowa river. The largest individual continuous area is found northwest of Marshalltown, separating the Tama upland from the bottoms along the Iowa river. South of Marshalltown the areas border Temple creek and generally separate the Tama upland from the Wabash bottoms. Frequently, however, areas of Shelby are found between the Clinton and the bottoms. In the southwestern corner of the county the Clinton is associated with the Lindley loam and is separated from the bottoms by areas of this type.

The surface soil of the Clinton silt loam is a light brown to brown, friable, smooth, silt loam, 6 to 8 inches in depth and underlaid by a brownish silty clay. The subsoil has a granular structure and is very compact, being hard when dry and plastic when wet. Light gray mottlings and yellowish-brown or reddish iron stains are frequently found in the lower sections of the subsoil.

In topography the soil is rolling to rough. The valleys are V-shaped, with steep slopes, and the type is subject to extensive erosion. Drainage is well established.

Practically all of the type was originally forested, chiefly with bur oak, white oak, red oak, hickory, butternut, red elm, dogwood, sumac, prickly ash and hazel brush. Probably 20 percent of the type is still in forest, but larger areas are gradually being brought under cultivation. Where the topography is favorable, corn and small grain crops are grown successfully. On the lower slopes, corn yields from 20 to 40 bushels per acre and oats give satisfactory yields. On the steeper areas neither of these crops proves very successful. Clover and timothy are quite generally grown and utilized for hay.

This soil is acid in reaction and in need of lime. It is low in organic matter and will respond to applications of farm manure. In fact, the use of this material is quite essential for the satisfactory production of corn and small grains on most areas. If farm manure is not available, leguminous crops should be utilized as green manures and every effort should be made to build up the supply of organic matter in the soil. The phosphorus content is not high and applications of phosphorus fertilizers might prove profitable at the present time. They will certainly be needed in the future. On the steeper areas erosion is extensive and prevention or control of this destructive action is very necessary. Probably in some cases it would be more desirable to utilize these steeper areas for pasture and thus prevent the washing away of the surface soil, which is apt to occur rapidly when soils are cultivated.

KNOX LOAMY FINE SAND (141)

This is a very minor soil type in the county, covering only 0.5 percent of the total area. It occurs in several small areas north and west of Marshalltown, north of Quarry and northwest from Albion, and is found along the edge of the uplands adjoining the first bottoms of the Iowa river. It occurs in lower areas than the Clinton silt loam.

The surface soil of the Knox loamy fine sand is a brown loamy fine sand, 6 to 8 inches in depth. The soil passes gradually into a loose, brownish-yellow fine sand, which at 20 inches changes in color to yellow or grayish-yellow. In topography the soil is undulating to hummocky, a condition which has been produced by wind action. Drainage is thoro to excessive, and crops are subject to injury by drouth.

Originally this soil was covered with bur oak, but about 60 percent is now under cultivation and is devoted to truck and cereal crops. Watermelons, cantaloupes and potatoes are grown very successfully. Corn and oats are grown to some extent, but give rather low yields, ranging in the case of corn from 15 to 20 bushels per acre, and for oats, from 15 to 25 bushels per acre. This soil is particularly in need of organic matter if it is to be made satis-

Fig. 11. The undulating topography of the Knox loamy fine sand in Marshall county has been produced by the action of the wind.

factorily productive. It is extremely low in both organic matter and nitrogen and likewise in phosphorus. Applications of farm manure are very desirable and leguminous crops as green manures would undoubtedly prove of value. The soil is acid and in need of lime. Phosphorus fertilizers could certainly be used with profit where general farm crops are grown. For the production of truck crops, other commercial fertilizing materials might also be used to advantage in certain cases.

TERRACE SOILS

There are three terrace types in the county, classed in the Waukesha, Buckner and Bremer series. They are minor in area, together covering only 2.9 percent of the total area of the county.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the largest terrace type, covering 1.4 percent of the total area of the county. It occurs in isolated areas along the Iowa river and along some of the smaller streams of the county. The largest areas are found north and west of Marshalltown, and small areas occur along Timber creek, Burnett creek, Asher creek, Mud creek and Linn creek.

The surface soil of the Waukesha silt loam is a dark brown, smooth, friable silt loam, about 18 inches in depth. This grades thru a brown heavy silt loam into a brownish-yellow silt loam subsoil, slightly heavier and more compact than the surface soil. The subsoil becomes lighter in color with depth, being yellowish in the lower part, and it has an open, friable structure. In topography the soil is gently undulating and drainage is usually adequate. It lies 10 to 20 feet above the present flood plains, and hence is not subject to overflow.

Nearly all of this type is under cultivation, general farm crops being grown. Corn yields 50 to 55 bushels per acre, oats 40 to 50 bushels and clover and timothy 1½ to 2½ tons per acre.

The Waukesha silt loam is a rather productive soil, but it will respond to certain fertilizer treatments. It is acid and in need of lime. It is not particularly high in organic matter, and will respond to applications of farm manure. It is not high in phosphorus and applications of phosphorus fertilizers would probably prove of value.

BUCKNER LOAM (38)

The Buckner loam is a minor soil type in the county, covering 1.3 percent of the total area. It occurs in small areas along the Iowa river and along Minerva creek, the larger areas being developed east and north of Clemons.

The surface soil of this type is a dark brown loam, 15 to 18 inches in depth. The subsoil is a yellowish-brown light textured loam to sandy loam. The surface soil varies somewhat in texture from a silty loam to a light textured loam, and some areas of sandy loam are included with the type. The subsoil contains a small amount of coarse sand and gravel and is rather open in texture. It is usually underlaid by fine gravel and sand beds at depths of 4 to 6 feet.

In topography the soil is flat and it contains low ridges, knobs, shallow depressions, channels and a few streams. Drainage is adequate to excessive, and in periods of drouth, crops are apt to suffer.

Practically all of the type is under cultivation. Corn is the leading crop and yields 35 to 45 bushels per acre. Oats give yields ranging from 30 to 40 bushels per acre, and clover and timothy yield 1½ to 2 tons of hay per acre. Potatoes grow well on this type.

This soil is acid in reaction and in need of lime. It is in need of organic matter to increase its water-holding power and prevent injury to crops during periods of drouth. Liberal applications of farm manure would prove of value and leguminous green manure crops should also be used in many cases. Phosphorus fertilizers would probably prove of considerable value on this soil.

BREMER SILTY CLAY LOAM (43)

This is a minor soil type in the county, covering only 0.2 percent of the total area. It occurs in three small areas, two along the Iowa river and one along Minerva creek, the largest area being found west of Minerva Junction.

The surface soil of this type is a black heavy silty clay loam, 18 to 20 inches in depth, grading into a dark slate colored plastic silty clay, faintly mottled with yellowish-brown. At 26 inches, the color changes to a yellowish-gray or bluish-gray mottled with yellowish-brown. In some places, below 8 inches, there is a subsurface layer of black silty clay. During periods of dry weather the soil is apt to crack. The subsoil is hard when dry and plastic and impervious when wet. In topography the type is flat to depressed and drainage is poor.

The soil is largely devoted to corn, yields of this crop averaging 50 bushels per acre. Wheat also does well, giving yields ranging from 20 to 30 bushels per acre. This soil is chiefly in need of drainage in order to make it more productive and, when tile is installed, satisfactory crop yields may be secured without additional treatment. Applications of farm manure would, however, undoubtedly be of value. Phosphorus fertilizers will be needed in the future.

SWAMP AND BOTTOMLAND SOILS

There are four swamp and bottomland soils in the county, three types which are classed in the Wabash series, and an area of muck. Together they cover 9.6 percent of the total area of the county.

WABASH SILT LOAM (26)

The Wabash silt loam is the most extensive bottomland type of the county, covering 7.0 percent of the total area. It occupies the first bottoms along the Iowa river, Minerva creek, Asher creek, Linn creek and Timber creek. It is also found along many of the smaller streams.

The surface soil of the Wabash silt loam is a heavy, smooth, nearly black silt loam, extending to a depth of about 20 inches. This is underlaid by a slightly heavier and more compact silt loam, slightly lighter in color. Frequently there is a little difference in the color or texture of the soils to a depth of 3 feet, and in places the lower subsoil is a dark colored, compact silty clay loam. Occasionally some sand has been mixed with the soil and pockets of sand are frequently found.

In topography the soil is generally flat and the drainage is frequently poor. Clearing and straightening the channels of streams has improved the drainage condition very materially. The type is subject to overflow.

This soil was originally forested with white elm, white ash, willow, cottonwood, box elder and walnut. In some areas the original tree growth still remains, while in others there is a luxuriant growth of marsh grasses. About 75 percent of the soil is devoted to the production of general farm crops. Corn is the chief crop grown and average yields of 50 to 60 bushels per acre are secured. Oats do well, yielding from 30 to 40 bushels per acre. A large part of the type is in hay and pasture.

This soil is very productive under favorable seasonal conditions, and is chiefly in need of adequate drainage and protection from overflow. Small amounts of farm manure would be of value, altho the soil is generally rich in organic matter. Applications of lime would be of value in some instances where the soil is acid, and phosphorus fertilizers will be needed in the future.

WABASH LOAM (49)

This is a minor soil type in the county, covering 1.4 percent of the total area. It occurs in small, narrow areas along the Iowa river and Minerva creek.

The surface soil is a dark grayish-brown to almost black loam to silty loam, 10 to 12 inches in depth, passing into a black loam subsoil which extends to a depth of 3 feet. Both soil and subsoil are friable and open. Occasionally streaks of gray sand are found thru the soil section, and some sand may occur on the surface. In topography the soil is flat, but drainage is quite adequate. The land is overflowed annually.

Along the larger streams the Wabash loam is forested and most of it is in pasture. In some areas the native grasses are cut for hay, yields ranging from 1 to 2½ tons per acre. About 10 percent of the type is devoted to the production of corn, average yields of 40 to 50 bushels per acre being secured. This soil is chiefly in need of protection from overflow in order to produce satisfactory crops. It would respond to applications of farm manure and probably also to phosphorus fertilizers.

WABASH SILTY CLAY LOAM (48)

This is a minor type in the county, covering 1.1 percent of the total area. It occurs along the first bottoms of the Iowa river and is found in numerous small areas. The largest areas are south of Marshalltown and northwest of Marshalltown.

The surface soil of this type is a black, crumbly, silty clay loam, 6 to 8 inches in depth, grading below this point into a black, sticky clay. From 24 to 36 inches, it changes to a dark slate color, slightly mottled with yellowish-brown. When dry, the soil is hard and compact and when wet, plastic and impervious. In topography the type is flat and slightly depressed. The drainage is very poor. It is subject to annual overflow.

Most of the type is now under cultivation and is largely devoted to corn, oats and hay. Corn yields 50 to 55 bushels per acre, oats 30 to 40 bushels per acre and hay 1 to 2 tons per acre. In wet seasons cultivated crops fail because of frequent overflow, but under normal conditions yields are quite satisfactory.

This type is chiefly in need of drainage in order to produce satisfactory crops. Protection from overflow is also needed. It is acid and in need of lime. Small applications of farm manure would probably be of value and phosphorus fertilizers will be needed in the near future.

MUCK (21a)

There is a very small area of muck in Marshall county, covering 64 acres or less than 0.1 percent of the total area of the county. It is developed in very small areas in the Carrington loam and is found in depressed, poorly drained spots.

Muck is largely made up of partly decomposed organic matter, and this organic material ranges from 24 inches to about 4 feet in depth. It rests on a subsoil of black clay, which changes to a lighter color at lower depths. Marsh grasses grow naturally in these areas and most of the type is used for pasture.

Muck is chiefly in need of drainage in order to be made productive, altho it is apt to be low in plant food constituents and, after being adequately drained, would probably respond to applications of phosphorus fertilizers. These areas of muck in Marshall county are so small that there is no need of considering their adaptation to special crops. They should be drained and brought under cultivation for growing general farm crops, such as are used on the surrounding uplands. Little difficulty is experienced in making these areas of muck satisfactorily productive if they are thoroly drained.

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 tyes, 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 soil 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 insure the best crop production.

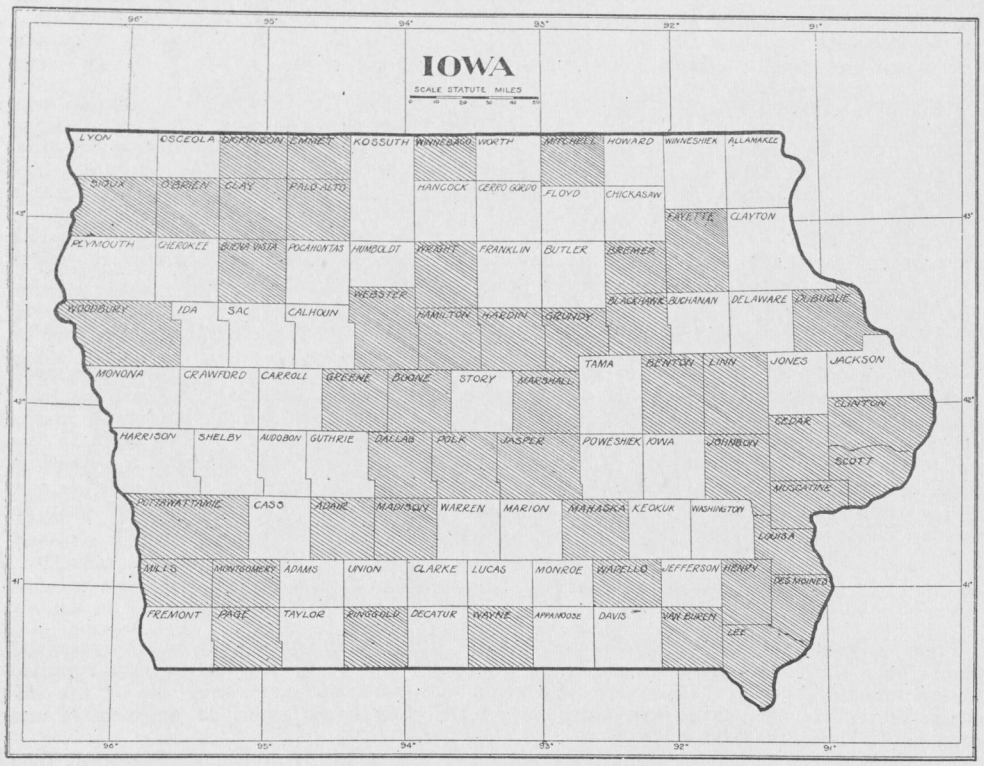

Fig. 12. Map of Iowa showing the counties surveyed.

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 accummulated 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 fertilizer 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 an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, application 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 *unavail-*

TABLE I. PLANT FOOD IN CROPS AND VALUE

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

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	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

able. 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 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 nitrogen, 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, phos-

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

REMOVAL FROM IOWA SOILS

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

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

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 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

*Bulletin 150, Iowa Agricultural Experiment Station.

present in the soil, it is relatively easy to keep them abundant and attention may be centered on those 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 to 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 a lack of the water necessary to bring them their food and also for a 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 periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

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 drouth may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. 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 large 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 percent 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 impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less

distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, 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 all 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 exception to the general rule, as was shown by the tests of many representative soils reported in bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

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

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 13.

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 or "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 stones. 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.

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 by and 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 or 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.