SOIL SURVEY OF IOWA

FREMONT COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section

Soils

Soil Survey Report No. 58

May, 1929

Ames, Iowa

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Report No. 58—FREMONT COUNTY SOILS

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

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

There is considerable acreage in waste land in the county, much of which might be reclaimed and made productive thru proper methods of soil treatment. General recommendations for the handling of unproductive lands cannot be given, as the causes of infertility are exceedingly variable. In a later section of this report special treatments are suggested for unproductive areas in the various soil types. Under more or less abnormal conditions, advice regarding treatment may be secured upon request from the Soils Section of the Iowa Agricultural Experiment Station.

THE CROPS GROWN IN FREMONT COUNTY

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

Corn is by far the most important crop, being produced, in 1927, on 52.3 percent of the total farm land of the county. Average yields per acre amount to 38.7 bu. The varieties preferred include Reid Yellow Dent, Boone County White and Iowa Silvermine. Much of the corn grown, however, is not purebred. Practically all of the crop is utilized on the farms as feed for the cattle, hogs, sheep and work animals. A small proportion is shelled and sold, but the practice is not common. Generally more corn is sold from the farms on the bottomlands than from those on the upland areas.

Wheat is the second crop in value and the third in acreage. Winter wheat is grown almost exclusively, and average yields amount to 19.9 bushels per acre. Wheat is a cash crop, and the grain is marketed at the local elevators or sold thru the farmers cooperative elevators.

Alfalfa is the second crop in value and the fourth in acreage. In 1927 it was produced on 2.9 percent of the total farm land and average yields amounted

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

Crops	Acreage	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	156,162	52.30	38.7	6,043,469	$0.69	$4,169,994
Oats	16,562	5.60	23.4	386,914	0.42	162,504
Winter wheat	13,513	4.50	19.9	269,568	1.17	315,395
Spring wheat	38	0.01	22.1	840	1.15	966
Barley	379	0.13	18.4	6,979	0.66	4,606
Rye	286	0.09	14.0	3,991	0.86	3,432
Clover hay†	3,948	1.30	1.74	6,870	12.50	85,875
Timothy hay	1,883	0.63	1.31	2,467	10.50	25,904
Clover and timothy hay (mixed)	1,834	0.62	1.27	2,329	11.77	27,412
All other tame hay	2,662	0.89	1.76	4,685	11.77	55,142
Alfalfa	8,275	2.90	3.11	25,735	16.00	411,760
Wild hay	1,124	0.39	1.04	1,169	10.00	11,690
Potatoes	266	0.08	66	17,556	1.00	17,556
Timothy seed	106	0.03	2.8	293	1.65	483
Clover seed†	1,334	0.44	0.87	1,161	16.10	18,692
Sweet clover seed	102	0.03	4.4	453	5.50	2,492
Sweet clover‡	9,683	3.20	------	--------	------	----------

*Iowa Yearbook of Agriculture, 1927.
†Sweet clover not included.
‡All varieties, for all purposes.

to 3.11 tons per acre. Under very favorable conditions yields as high as 6 tons per acre have been obtained. From three to five cuttings are sometimes made each season. The value of alfalfa hay as a livestock feed is generally recognized, and the crop is grown extensively on the better livestock farms. It grows well on most of the soils of the county, especially on the types which are well supplied with lime. Inoculation is desirable for this crop if it has not been grown previously and sweet clover has not been produced on the area. Liming may sometimes be needed if the soil is acid in reaction. With these precautions, the crop proves very successful.

Oats are the third crop in acreage and the fourth in value. In 1927 this crop was grown on 5.6 percent of the farm land. Average yields amount to 23.4 bushels per acre. The varieties grown include Kherson, Iowa 103, Iowa 105, Early Champion and Green Russian. The oats crop is used mainly as feed for the work animals, very little of the crop being sold out of the county. In many cases, on the better farm areas, the yields of oats are very high. The range has been estimated from 25 to 72 bushels per acre. The crop serves as an excellent nurse crop for clover, alfalfa and sweet clover, and it is commonly included in the rotation where the legumes are to be grown.

Clover is the chief hay crop, average yields amounting to 1.74 tons per acre. Some timothy is grown alone, yielding 1.31 tons per acre. Clover and timothy mixed is utilized as a hay crop on many farms, yielding 1.27 tons per acre. There is a small area in wild hay, yielding 1.04 tons per acre. Some clover is grown for seed and some timothy is produced for seed. Sweet clover is grown on a limited acreage and is proving very successful. Most of the crop is pastured, the residues being plowed under in the spring for green manuring purposes. Small acreages are cut for hay but this practice is not general. The biennial sweet clover is most commonly grown. Hubam, the annual sweet clover, is raised only on small areas. Sweet clover makes an excellent pasture crop and is of very large value for green manuring purposes as a means of increasing the organic matter content and nitrogen in the land. It grows excellently on soils high in lime and therefore thrives on the soils on the slopes of the Missouri River bluffs. Practically all of the hay produced in the county is utilized for feed but occasionally there is some alfalfa or other hay sold on the market.

Minor crops produced include rye, barley, potatoes, tree and bush fruits and garden vegetables. Orcharding is practiced to some extent and there are a few commercial orchards and some sale of apples out of the county.

THE LIVESTOCK INDUSTRY IN FREMONT COUNTY

The extent of the livestock industry in Fremont County is indicated by the following figures taken from the Iowa Monthly Crop Report for July 1, 1928, giving the Jan. 1, 1928, estimates of the Bureau of Agricultural Economics of the United States Department of Agriculture in cooperation with the Iowa State Department of Agriculture:

Horses	8,900
Mules	2,570
Cattle, all	21,300
Hogs	85,300
Sheep	500

The raising of hogs is the most important livestock industry and in 1928 there were 85,300 head of hogs on the farms of the county. Poland China, Hampshire, Tamworth and Duroc Jersey are the most common breeds. The sale of hogs provides the chief source of income on most farms.

The cattle industry is second in importance, the raising and feeding of beef cattle being practiced quite commonly. The beef cattle are purchased on the Omaha market as feeders, pastured during the summer and fed for from 90 to 120 days before being marketed. Hereford, Aberdeen Angus and Shorthorn breeds are preferred for feeding purposes.

Dairy cattle are raised and dairying is practiced commercially on a few farms located near the larger towns. Milk and cream are supplied to local consumers and the surplus is sold at the local creameries. Jersey, Guernsey and Holstein-Friesian or grades of these breeds are preferred. On most farms dairy cattle are kept only in sufficient numbers to supply the home demand for butter, milk and cream. A few sheep are raised on the farms in the more hilly sections of the county but the industry is of very minor importance. A considerable number of sheep are shipped in for feeding purposes, and some farmers fatten several hundred head each year and market them at St. Joseph and Omaha. Sheep feeding is practiced almost exclusively on the bottomlands. Horses and mules are kept for work stock on all farms. One or two colts are raised per farm each year to supply the local needs. Belgian, Percheron and Clydesdale grades are found most commonly thruout the county.

Poultry raising is practiced generally thruout the county, most farmers raising sufficient to supply the home demand. The surplus poultry and poultry products are disposed of on the local markets. With more attention paid to the poultry, a larger income might be provided on many farms.

THE FERTILITY SITUATION IN FREMONT COUNTY

In general the crop yields secured in Fremont County are fairly satisfactory but in some cases much larger yields might be secured by the adoption of proper methods of soil management.

In some sections drainage conditions are not entirely satisfactory, and the soils will not give the best crop yields until adequate drainage has been established. This situation is found in certain areas on the terrace and bottomland types. The upland soils of the county are generally well drained and are very rarely in need of tiling. On the Judson and Bremer soils on the terraces, however, and on the Wabash and Lamoure types on the bottoms, drainage is essential for satisfactory crop growth. The straightening and deepening of the natural stream channels on these bottomland areas would aid materially in improving drainage conditions and the installation of tile would also be of value.

Some of the soil types in the county are light in color and low in organic matter and nitrogen. On these soils and especially in the case of those which are sandy in texture, the use of fertilizing materials supplying organic matter is particularly necessary to provide for the most satisfactory crop yields. Even on these types which are darker in color and apparently better supplied with organic matter, it is very necessary that fertilizing materials supplying this constituent be used regularly if the content is to be kept up. Applications of farm manure are of especially large value on the light-colored sandy soils like the Shelby, Knox, Hancock, Cass and Sarpy types, but they are also very effective on the richer soils like the Marshall and Waukesha and small applications may be of value on the very rich black Bremer, Wabash and Lamoure types. Farm manure is certainly one of the most valuable fertilizing materials which can be employed. The use of leguminous crops as green manures will be profitable on many of the soils, especially the lighter-colored, coarser-textured types, but it will also prove of value on many farms as a supplement to, or as a substitute for, farm manure.

A number of the soil types are acid in reaction, and applications of lime are necessary for the best growth of general farm crops, particularly of legumes. Some of the types like the Knox on the upland, the Hancock on the terraces, the Lamoure, Cass and Sarpy types on the bottoms, are well supplied with lime. The Shelby and Marshall soils on the uplands, the Judson, Waukesha and Bremer types on the terraces, and the Wabash soils on the bottoms are, however, deficient in lime. These types should be tested for lime needs and applications of lime should be made as necessary, if the most satisfactory yields of general farm crops and especially of legumes are to be secured.

The soils of Fremont County are generally rather low in phosphorus content, and it is apparent that applications of phosphorus fertilizers will be needed on these soils in the very near future even if they are not necessary now. Experiments which have been carried out on some of the main soil types in the county, however, have indicated that phosphorus fertilizers may prove profitable in many cases at the present time. The experiences of many farmers have also shown the possibility of profit from the use of superphosphate or rock phosphate. On the lighter-colored soils it is very desirable that tests with superphosphate be carried out to determine its value. On the darker-colored, richer soils, both superphosphate and rock phosphate may be tested. By such means, farmers may determine the value of the phosphate fertilizers under the particular conditions and decide which material may be used most profitably.

Complete commercial fertilizers may be used profitably in the county in some cases, but in general it would seem, from the experiments which have been carried out, that superphosphate or rock phosphate might be employed with greater profit. The phosphates are less expensive, hence the complete fertilizers must bring about much larger increases in crops to prove as economical. For general farm crops complete fertilizers should not be employed until tests have been carried out comparing the value of the particular brand with superphosphate. If the material proves profitable, it may then be employed on extensive areas with the assurance of profit. For special crops, such as truck crops, complete fertilizers may be used to advantage.

Commercial nitrogenous fertilizers are not recommended for general use at the present time. Ordinarily nitrogen may be supplied to the land more satisfactorily and cheaply by the use of leguminous green manures, by the proper preservation and application of farm manure, and by the thoro utilization of crop residues. Only in special cases for certain crops will it be desirable to supply commercial nitrogen. In such cases, small amounts as top dressings might be used with profit.

The soils of the county are generally well supplied with potassium and additions of commercial potassium fertilizers would not be expected to give large effects. Such fertilizers may sometimes prove profitable, but extensive applications should not be made until tests have been carried out and the material has been shown to be of value. Farmers who are interested should test these materials on small areas to determine their value.

Erosion occurs to a limited extent in the county, the Shelby loam being the type most generally affected. There is some erosion, however, in the Marshall silt loam, and the Knox silt loam is frequently badly gullied. Wherever this destructive action takes place, some method for the prevention or control of erosion should be adopted.

THE GEOLOGY OF FREMONT COUNTY

The soils of Fremont County have not been affected to any appreciable extent by the underlying bedrock. The deposits of glacial drift and loess laid down over the surface of the land in the more recent geological ages have buried the native rock material so deeply that it has exerted no influence on the characteristics of the soils at the present time.

During the period in geological history known as the glacial age at least one and probably two great glaciers or ice sheets swept over the county and upon their retreat left behind vast deposits of glacial drift or till. The major part of this deposit of drift or glacial debris, or perhaps all of it, was left behind by the Kansan glacier and is known as the Kansan drift. The deposit is extremely variable in depth, ranging from about 50 feet in the western part of the county to 150 feet in the eastern part.

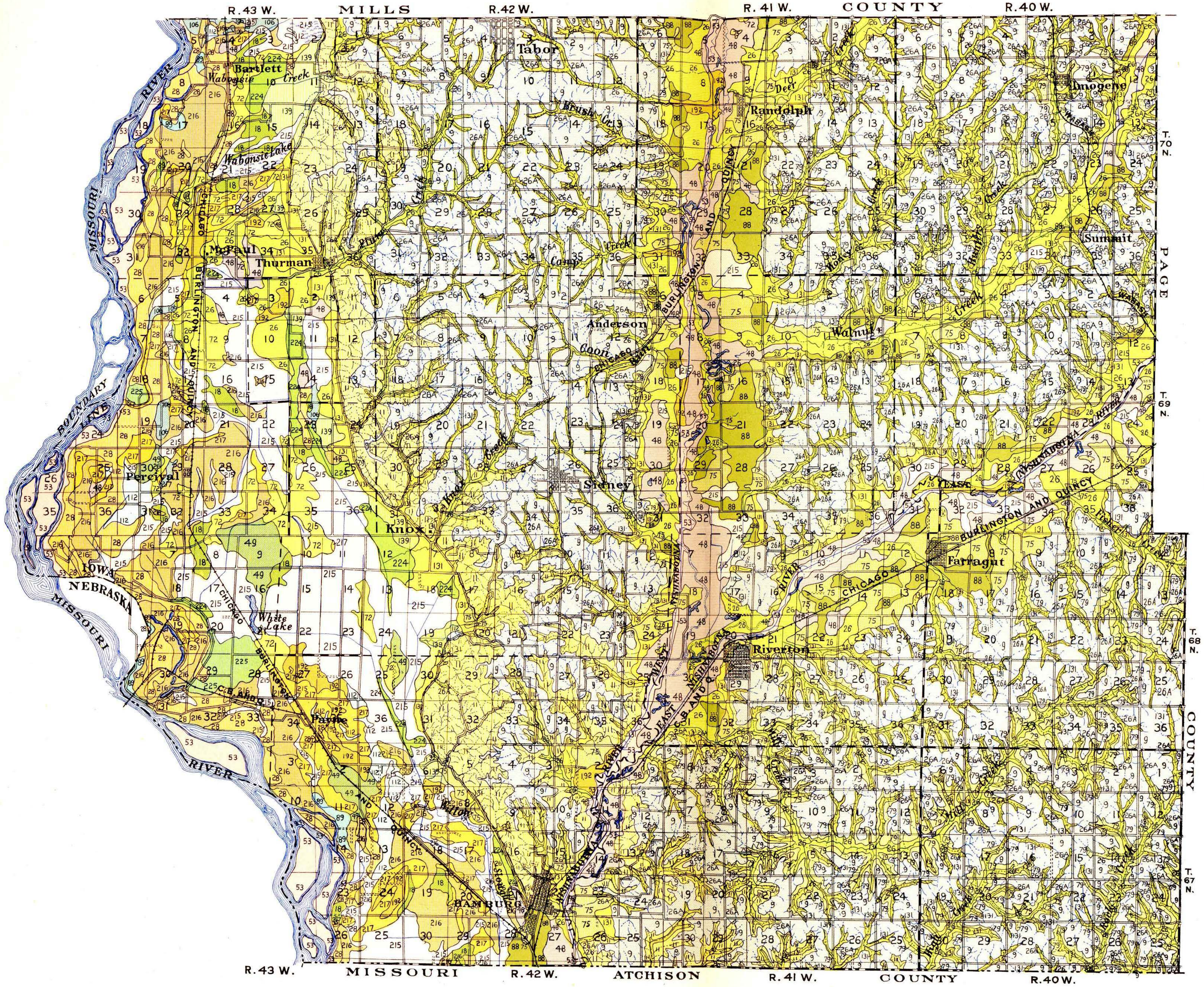
The drift material is a yellow boulder clay containing considerable amounts of fine sand, coarse sand, and numerous boulders. Weathering has changed the color of the material at the surface to a darker yellow and in some cases to almost a red. The accumulation of organic matter has aided in the darkening of the color of the soil. Below this Kansan drift deposit, there is a layer of glacial material undoubtedly of earlier origin. It is darker in color and consists of layers of silty materials and sand. These earlier deposits have not affected the soils of the county. One soil type which has been mapped is derived from the Kansan drift. This is the Shelby loam, which is developed along the streams in the eastern part of the county where the loess covering has been largely removed by erosion.

At a much later geological era, when climatic conditions were very different than at present, a layer of silty material known as loess was laid down over the surface of the county. The deposit varies widely in thickness, due to the erosion which has occurred since its deposition. On the former hill tops and ridges, the layer is much thinner, and in the eastern part of the county, where erosion has occurred more extensively the deposit is thinner and may even be lacking along the streams. In the old valleys the loess is deeper. In general the deposit is thicker in the western part of the county and thins out toward the east. The range in depth has been estimated at from a few feet to 100 feet. In an unweathered condition, the loess is a pale yellow to yellowish-brown, even grained, silty material. It has the property of standing in cuts, and frequently concre-

Thomas D. Rice, Inspector, Northern Division. Soils surveyed by C. L. Orrben, of the Iowa Agricultural Experiment Station, and L. S. Paine of the U. S. Dept. of Agriculture.

SOIL MAP OF FREMONT COUNTY IOWA

Henry G. Knight, Chief. A. G. McCall, Chief, Soil Investigations
Curtis F. Marbut, in charge Soil Survey
IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtiss, Director W. H. Stevenson, in charge Soil Survey
P. E. Brown, Associate in Charge



LEGEND

Drift Soils

79 — Shelby loam

Loess Soils

9 — Marshall silt loam
11 — Knox silt loam

Terrace Soils

131 — Judson silt loam
75 — Waukesha silt loam
88 — Bremer silt loam
139 — Hancock very fine sandy loam
224 — Hancock very fine sandy loam (Shallow phase)
225 — Hancock fine sand Shallow phase

Swamp and Bottomland Soils

26 — Wabash silt loam
26A — Wabash silt loam (Colluvial phase)
215 — Lamoure silty clay
48 — Wabash silty clay loam
216 — Cass silty clay
28 — Sarpy very fine sandy loam
53 — Riverwash
217 — Cass very fine sandy loam
72 — Wabash clay
192 — Wabash very fine sandy loam
49 — Wabash loam
18 — Cass loam
112 — Lamoure loam
106 — Cass silt loam
89 — Sarpy silt loam

SCALE: 1 INCH TO 2½ MILES

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

tions of calcereous material are found thruout the soil section and usually in the lower part of the 3 foot section.

The weathering to which the soils have been subjected and the accumulation of organic matter from plant growth has darkened the color of the surface soil and has led to a very large removal of lime from the surface layer. The Marshall silt loam and the Knox silt loam are the two loess soils developed in this county. The Marshall silt loam is found on the more gently rolling to undulating areas and it is dark brown in color and rarely contains lime in the surface soil. Sometimes the dark color continues thruout the 3 foot section and occasionally the lime has been removed to that depth. In the more strongly rolling areas, where erosion has occurred to some extent and the surface soil has been partially removed, the loess deposit is thinner and the color of the soil is apt to be somewhat lighter. On the steeper areas and along the bluffs of the Missouri River, the Knox silt loam has developed. This is an extremely light colored type showing a high content of lime thruout the soil section.

The soils on the terraces and bottomlands have been formed mainly from the material carried down from the loessial uplands. Occasionally there has been some admixture of glacial material, but the bottomland soils are chiefly derived from the loess deposit.

PHYSIOGRAPHY AND DRAINAGE

Originally the surface of Fremont County was a level plain. The larger tributaries of the Missouri River and the numerous smaller streams have cut thru the loessial materials into all part of the county, giving it the present rolling or hilly surface. Along the streams, areas of flat terraces and bottomlands have developed.

Three rather distinct topographic divisions of the land in the county are recognized; the rolling uplands, the steep bluffs along the Missouri River bottoms, and the broad bottomlands along the Missouri and Nishnabotna Rivers. The more gently rolling upland areas are found between the Missouri bluffs and the West Nishnabotna River, north of Walnut Creek in the northeastern section, and south of the East Nishnabotna River in the southeastern part of the county. In these areas the slopes are smooth and gentle, the ridges are well rounded and the valleys are wide.

A strip of distinctly hilly or broken land, varying from ½ to 2 miles in width, occurs east of the bottomlands of the Missouri River and extends from the northern county line to within 1½ miles of the southern county line. In this area the steep bluffs rise from 150 to 250 feet above the bottomlands. The slopes are steep, the ridges are narrow and the stream valleys are V-shaped. Erosion occurs to a considerable extent in this area, and the slopes are sometimes badly washed. In the southern part of the county, where the Nishnabotna River bottoms join the Missouri bottomlands, all that remains of the old upland plain is a narrow ridge. This ridge extends into the northern part of the city of Hamburg. On the slopes of the bluffs facing the river bottoms there is little vegetation, but the ridges and slopes to the east are covered with timber and grasses.

The bottomland plain along the Missouri River is 200 to 330 feet below the level of the higher uplands. The plain varies from 3 miles in width in the ex-

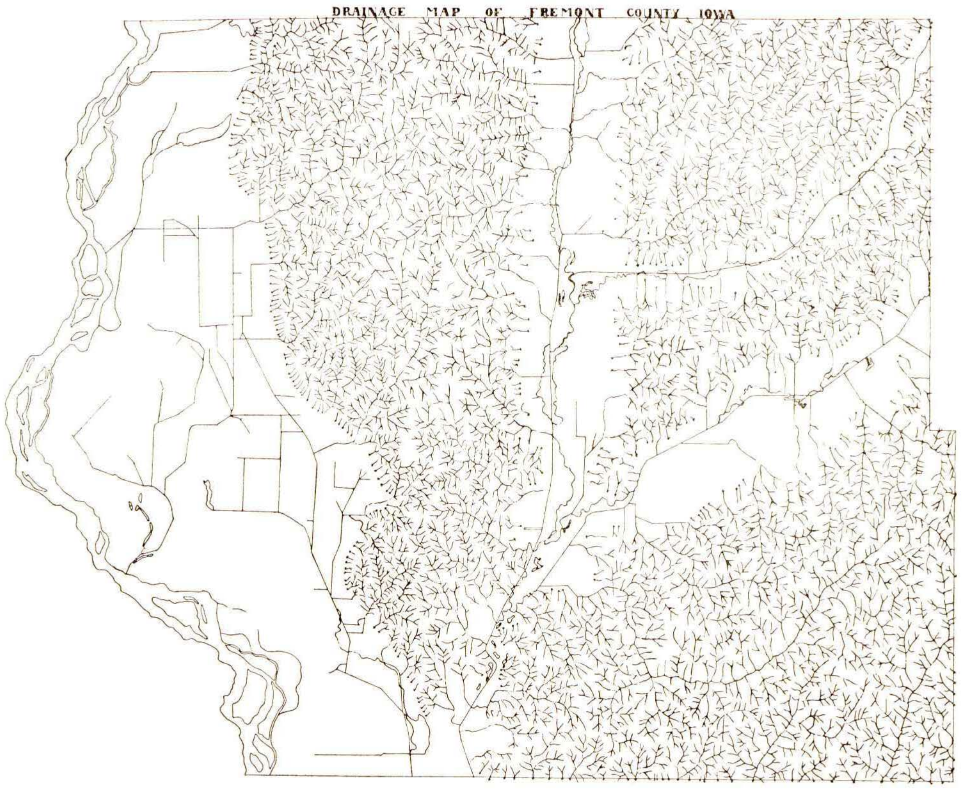


Fig. 2. Map of Fremont County showing natural drainage system.

treme northern part of the county to about 10 miles in width at the widest point. It is level or undulating in topography, the level areas occurring from 2 to 4 miles east of the river and the hummocky or undulating areas being found bordering the river. There are numerous old sloughs or channels thruout the bottomland. The bottomlands along the Nishnabotna Rivers are similar to those along the Missouri. The valleys are broad and the uplands bordering them are hilly.

At the base of the steep slopes along the Missouri River bottomlands are areas from ¼ to 1½ miles in width of second bottomland or terrace. These areas have been formed by deposits from the smaller streams during freshets. The areas lie from 20 to 40 feet above the adjacent bottomland and have a gradual slope to the westward. The largest terrace deposit is at Thurman, where Plum Creek enters the bottomland plain. Numerous terraces also occur along the Nishnabotna Rivers. The largest area is found in the northern part of the county, the town of Randolph being built on the east side of it. The towns of Farragut, Anderson, Riverton and Hamburg are built on extensive terraces.

The drainage of the county is brought about by the Missouri River and its tributaries, the chief of which are the Nishnabotna River, the West Nishnabotna River and the East Nishnabotna River. Some of the important minor streams in the county are Wabonsie Creek, Plum and Knox Creeks in the west-

ern part of the county; Camp Creek, Coon Creek, Brush Creek, Deer Creek, Honey Creek, Walnut Creek and Hunters Creek, branches of the West Nishnabotna River in the central part of the county; Fisher Creek and Mill Creek, branches of the East Nishnabotna River in the southeastern part of the county; and High Creek and Rock Creek which drain the southeastern corner of the county.

Except for the Missouri River bottomlands, every square mile of land in the county has two or more drainage outlets. In the more hilly regions, considerable damage is done by erosion. The beds of many of the intermittent streams lie from 20 to 45 feet below the level of the bottomland deposits. In the more gently rolling areas, the bottoms are wide when compared with the size of the streams.

The accompanying drainage map indicates the extensive natural drainage system of the uplands of the county. The need for drainage is largely restricted to the broad areas of bottomland. Some of the terrace types are in need of tiling and in many of the bottomland soils artificial drainage is needed. Only occasionally in the uplands is there need for drainage.

THE SOILS OF FREMONT COUNTY

The soils of Fremont County are grouped into four classes according to their origin and location: Drift soils, loess soils, terrace soils, and swamp and bottomland soils. Drift soils are those which have been deposited by glaciers and contain material derived from various sources, usually including pebbles and boulders. Loess soils are fine dust-like deposits made by the wind at some time when climatic conditions were different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams by which they were formed 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 total areas and percent of the acreage of the county included in these four groups are shown in table II.

There is one drift soil in the county, covering 6.8 percent of the total area. The loess types cover more than one third of the area, 39.5 percent. The terrace soils are rather extensively developed, covering 12.1 percent of the total area. The swamp and bottomland soils are very extensive, covering 41.6 percent of the total area.

There are 20 individual soil types, and these with the shallow phase of the Hancock very fine sandy loam, the shallow phase of the Hancock fine sand, the colluvial phase of the Wabash silt loam and the area of Riverwash make a total

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

Soil Group	Acres	Percent of total area of county
Drift soils	22,400	6.8
Loess soils	129,664	39.5
Terrace soils	39,552	12.1
Swamp and bottomland soils	136,704	41.6
Total	328,320	------

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN FREMONT COUNTY

Soil No.	Soil Type	Acres	Percent of total area of county
	DRIFT SOILS		
79	Shelby loam	22,400	6.8
	LOESS SOILS		
9	Marshall silt loam	108,800	33.1
11	Knox silt loam	20,864	6.4
	TERRACE SOILS		
131	Judson silt loam	14,656	4.5
75	Waukesha silt loam	10,816	3.3
88	Bremer silt loam	8,128	2.5
139	Hancock very fine sandy loam	2,624	1.5
224	Hancock very fine sandy loam (shallow phase)	2,304	
225	Hancock fine sand (shallow phase)	1,024	0.3
	SWAMP AND BOTTOMLAND SOILS		
26	Wabash silt loam	29,312	15.3
26a	Wabash silt loam (colluvial phase)	21,120	
215	Lamoure silty clay	22,592	6.9
48	Wabash silty clay loam	14,272	4.4
216	Cass silty clay	11,776	3.6
28	Sarpy very fine sandy loam	8,640	2.6
53	Riverwash	8,128	2.5
217	Cass very fine sandy loam	5,952	1.8
72	Wabash clay	4,992	1.5
192	Wabash very fine sandy loam	2,880	0.9
49	Wabash loam	2,048	0.6
18	Cass loam	2,112	0.6
112	Lamoure loam	1,536	0.5
106	Cass silt loam	768	0.2
89	Sarpy silt loam	576	0.2
	Total	328,320	------

of 24 separate soil areas. There are 1 drift soil, 2 loess types, 6 areas of terrace soils and 15 areas of swamp and bottomland. These various soil types are distinguished on the basis of certain definite characteristics which are described in the appendix to this report. The areas covered by the individual soil types are shown in table III.

The Shelby loam, the only drift type in the county, is the fourth largest soil, covering 6.8 percent of the total area. The Marshall silt loam is the most extensively developed individual type, covering 33.1 percent of the county. The Knox silt loam is the second loess type and the fifth largest soil, covering 6.4 percent of the total area. The terrace soils are all limited in extent, the Judson silt loam being the largest. It covers 4.5 percent of the county. The Waukesha silt loam, the Bremer silt loam and the Hancock very fine sandy loam, together with the shallow phase, cover 3.3 percent, 2.5 percent, and 1.5 percent of the total area respectively. The shallow phase of the Hancock fine sand covers only 0.3 percent of the area.

The Wabash silt loam is the largest bottomland type and the second largest type in the county. Together with the colluvial phase, which is extensively developed, this soil covers 15.3 percent of the total area. The Lamoure silty clay is the second largest bottomland soil and the third most extensively developed type. It covers 6.9 percent of the area. The Wabash silty clay loam covers 4.4 percent, the Cass silty clay 3.6 percent, the Sarpy very fine sandy loam 2.6 percent, Riverwash 2.5 percent, the Cass very fine sandy loam 1.8 percent and the Wabash clay 1.5 percent of the total area of the county, respectively. The remaining bottomland types each cover less than 1 percent of the total area.

There is a rather definite relationship between the topography of the soil on the uplands and the types developed there. The Shelby loam occurs on the more steeply rolling to abrupt areas of upland along the streams and intermittent drainageways. The Marshall silt loam, the most extensive upland type, generally has a gently rolling to smoothly rolling topography. The Knox silt loam occurs on the abrupt to steep bluffs along the Missouri River bottomland. It is steep to rough and broken in topography. On the terraces and bottoms topographic features are not definitely developed. Occasionally there is a slightly undulating topography, and the terraces usually slope gently toward the bottomlands. The bottomland areas are mainly level to flat.

The Fertility in Fremont County Soils

Samples were taken for analysis from all the soil types of the county. The area of Riverwash was not sampled as it is so variable in composition that an analysis would mean nothing. The more extensive soil types were sampled in triplicate, but only one sample was taken from the minor types. All samplings were made with the greatest care that the samples should be thoroly representative of the soil types and that all variations due to local conditions or previous treatments should be eliminated. Samples were taken at three depths, 0 to 6 2/3 inches, 6 2/3 to 20 inches and 20 to 40 inches, representing the surface soil, subsurface soil and subsoil, respectively.

The total phosphorus, total nitrogen, total organic carbon and inorganic carbon content, and the limestone requirements of the soils were determined. The official methods were used for the phosphorus, nitrogen and carbon determinations, and the limestone requirement determinations were made with the Truog qualitative test. The figures given in the tables are the averages of the results of duplicate determinations on all samples of each type and they represent, therefore, the averages of two or six determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2 million pounds of surface soil per acre. There is a rather wide variation in the phosphorus content of the soils of the county, the amount present ranging from 1,023 pounds per acre in the Shelby loam up to 2,280 pounds per acre in the Judson silt loam. There seems to be little relationship between the phosphorus supply and the various soil groups, altho there is a larger amount present in the bottomland soils, on the average, than in the upland types. The terrace types also seem to be somewhat higher in the element than the upland soils. This difference might be expected inasmuch as the terrace and bottomland soils have not been cropped so heavily and hence

TABLE IV. PLANT FOOD IN FREMONT COUNTY, IOWA, SOILS
Pounds per acre of 2 millon pounds of surface soil (0 to 6⅔")

Soil No.	Soil Type	Total phos-phorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone require-ment
	DRIFT SOILS					
79	Shelby loam	1,023	2,800	28,224	-------	5,000
	LOESS SOILS					
9	Marshall silt loam	1,207	3,680	37,203	-------	3,667
11	Knox silt loam	1,047	1,760	15,328	188	None
	TERRACE SOILS					
131	Judson silt loam	2,280	3,520	42,677	-------	4,000
75	Waukesha silt loam	1,506	3,360	36,141	-------	3,000
88	Bremer silt loam	1,798	4,080	39,659	-------	2,500
139	Hancock very fine sandy loam	1,495	2,120	16,404	2,248	None
224	Hancock very fine sandy loam (shallow phase)	1,306	1,880	18,336	2,089	None
225	Hancock fine sand (shallow phase)	1,171	1,080	13,843	14,626	None
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,495	3,640	35,641	-------	3,000
26a	Wabash silt loam (colluvial phase)	2,208	5,680	67,356	-------	4,000
215	Lamoure silty clay	2,100	5,160	48,489	9,896	None
48	Wabash silty clay loam	1,481	4,000	55,630	-------	2,000
216	Cass silty clay	1,427	3,640	31,465	2,540	None
28	Sarpy very fine sandy loam	1,104	1,720	9,364	10,570	None
217	Cass very fine sandy loam	1,966	3,960	37,578	-------	1,000
72	Wabash clay	1,522	3,440	36,625	-------	None
192	Wabash very fine sandy loam	1,481	2,080	22,562	-------	None
49	Wabash loam	1,643	3,600	37,087	-------	3,000
18	Cass loam	1,657	3,400	37,680	743	None
112	Lamoure loam	1,872	3,160	37,687	1,799	None
106	Cass silt loam	1,414	2,080	15,063	7,898	None
89	Sarpy silt loam	1,481	1,800	18,339	13,566	None

there has been a smaller removal of the element. In general, however, there are wider variations in phosphorus within groups than between groups.

Some relationships are evidenced between the various soil series and soil types mapped and the content of phosphorus. Thus on the uplands the Shelby loam is the lowest and the Knox silt loam is lower than the Marshall. On the terraces the Judson is the richest in phosphorus, the Bremer is second, the Waukesha is third and the Hancock types are the lowest. On the bottomlands the Wabash and Lamoure types are the highest, but one of the Cass soils is as high in the element as some of the types of these series. The Sarpy types, however, are lower than the other soils. It would seem that there is some relationship between the characteristics which determine the soil series and the phosphorus content. Thus the color, topographic position, origin and subsoil character may indicate the content of phosphorus. The Marshall silt loam on the uplands is more gently undulating in topography and is higher in phosphorus than the Knox and Shelby types. The loess soils are richer than the Shelby loam which is of drift origin. The Bremer, Judson and Waukesha soils are higher in phosphorus than the lighter-colored Hancock types. The Wabash, Lamoure and Cass soils are higher in the element than the light-colored Sarpy types, and the Wabash and Lamoure soils are richer than the Cass soils and have heavier subsoils.

Some relationships between the phosphorus supply and the texture of the soil are also shown. The Hancock very fine sandy loam is richer than the shallow phase of the type and the fine sand of the same series. The colluvial phase of the Wabash silt loam is richer than the silt loam, but the Wabash silty clay loam is a little lower in phosphorus than the silt loam. The Wabash clay is lower than the colluvial phase of the Wabash silt loam and the Wabash loam is higher than the silt loam. The very fine sandy loam of the same series has about the same content as the finer-textured types. In general, however, the differences among these various soils are small and probably reflect the variations which normally occur in bottomland types. The Lamoure silty clay is richer than the Lamoure loam. The Cass silty clay is richer than the Cass silt loam, but the Cass very fine sandy loam and the Cass loam are higher than the silt loam. These differences also undoubtedly reflect variations in the particular samples. The Sarpy silt loam is richer in the element than the very fine sandy loam. In general, the results bear out previous conclusions, indicating that fine-textured types are richer in plant food than coarse-textured soils. Thus silty clay loams are generally richer than silt loams and these in turn are better supplied than loams or sandy loams.

As a whole the analyses indicate that the supply of phosphorus in the soils of the county is not sufficient to meet the needs of crops for an indefinite period. Phosphorus fertilizers will certainly be needed in the near future and in some cases their use will undoubtedly prove profitable at the present time. The experiments which have been carried out with rock phosphate and superphosphate, and the experiences of many farmers with these materials, indicate the desirability of their use in many cases now. Definite recommendations regarding the desirability of using one or the other of the phosphorus carriers on the various soil types cannot be given at the present time, but it is urged that farmers test both materials under their particular conditions. For soils light in color and low in organic matter, the use of superphosphate would undoubtedly be preferable.

The nitrogen content of the soils of the county is somewhat variable, ranging from 1,080 pounds per acre in the shallow phase of the Hancock fine sand up to 5,680 pounds in the colluvial phase of the Wabash silt loam. On the average the bottomland types are richer in nitrogen than the soils in the other groups, and the terrace types are somewhat better supplied than the upland soils. This might be expected, inasmuch as the bottomland soils have been cropped to a lesser extent and hence there has been a smaller removal of the element.

The characteristics which serve to distinguish the various soil series apparently have an effect on the nitrogen content. Thus the Marshall silt loam on the loessial uplands is higher than the Knox and Shelby soils. It is darker in color and more gently rolling in topography. The Bremer, Waukesha and Judson soils on the terraces are richer than the Hancock types and are darker in color. There are differences in texture here, however, which also affect the plant food content. The Wabash and Lamoure soils on the bottomlands are somewhat richer in nitrogen than the other types. The textural differences among these bottomland soils are, however, of more importance than the series separations.

A few comparisons from the textural standpoint are possible. Thus the Hancock very fine sandy loam is richer than the other Hancock types. The Lamoure silty clay in richer than the Lamoure loam. The Cass silty clay is higher than the Cass loam or the Cass silt loam. The very fine sandy loam of this series, however, is the richest in phosphorus, probably due to some abnormal condition in the sample. The Sarpy silt loam is higher in nitrogen than the very fine sandy loam. The Wabash silty clay loam is lower in nitrogen than the colluvial phase of the silt loam but it is higher than the typical silt loam, which in turn is higher than the loam. The very fine sandy loam is the lowest of the Wabash types. Apparently, fine-textured soils are generally much better supplied with nitrogen than are the coarse-textured types. Silty clay loams may ordinarily be expected to be richer in nitrogen than silt loams. Silt loams are usually richer than loams, and loams are better supplied than the sandy types.

Most of the soils in Fremont County are fairly well supplied with nitrogen, altho some are rather poorly supplied. In all cases where the nitrogen content is rather low, the addition of some fertilizing material supplying nitrogen is very necessary, but even on the types which are darker in color and apparently richer in nitrogen, this element must not be overlooked when systems of permanent fertility are planned. The proper preservation and application of all the farm manure produced will aid materially in keeping up the nitrogen supply in the soil. The thoro utilization of all crop residues will also aid in this connection. The turning under of leguminous crops as green manures is the cheapest and best means of increasing the nitrogen content in the soil. Legumes utilize the free nitrogen of the atmosphere to a very large extent, hence, when they are turned under as green manures, there may be a very large addition of nitrogen to the soil. On many of the soil types in this county green manuring would prove of large value. Green manuring is an especially desirable practice on grain farms and is also profitable on many livestock farms to supplement farm manure.

The total organic carbon content of the soils indicates the amount of organic matter present. The color of the soils shows roughly the amount of organic matter and nitrogen, hence there is generally a close relationship between the color of soils and the actual amounts of nitrogen and organic carbon present. Black soils are generally high in organic matter and nitrogen, and light-colored soils may be expected to be more or less deficient in these constituents. The actual relationship between the carbon and nitrogen content indicates fairly accurately the rate at which plant food is made available in the soil. If this relationship is not right, there will be a low production of available plant food and crops may suffer.

On some of the soils in Fremont County the relationship between carbon and nitrogen is not at the optimum, and it is important that some method be adopted to improve the relationship and stimulate the production of available plant food.

The use of farm manure is particularly important in this connection as it has a large effect on the production of assimilable constituents. The Shelby loam on the drift upland, the Marshall silt loam on the loessial upland, the Knox silt loam, the Waukesha silt loam, the Bremer silt loam and a number of the bottomland types are particularly in need of farm manure to stimulate the transformation of unavailable plant food into easily utilizable forms.

The amount of organic matter present in the soils ranges from 9,364 pounds per acre in the Sarpy very fine sandy loam up to 67,356 pounds in the colluvial phase of the Wabash silt loam. As in the case of nitrogen, there is some relationship between the organic matter content and the soil groups, the soil series and the individual soil types. The bottomland soils are, on the average, better supplied than the upland types. The terrace soils are somewhat richer than the upland soils. The Marshall silt loam is much better supplied than the Knox on the loessial upland, which is a reflection of the darker color and more level topography of the Marshall. The Judson, Waukesha and Bremer soils are richer than the Hancock types on the terraces. This is likewise a reflection of the darker color of the three types mentioned. On the bottomlands the Wabash, Lamoure and Cass soils are richer than the Sarpy, a difference indicated in their darker color. The Wabash and Lamoure soils are, on the average, richer than the Cass types, due to their heavier subsoil characteristics.

Similar relationships between the texture of the soil and the organic carbon content are indicated as in the case of nitrogen, but only a few comparisons are possible. The Hancock very fine sandy loam is richer than the fine sand. The Wabash silt clay loam is higher than any of the other Wabash types except the colluvial phase of the Wabash silt loam. The Wabash clay is higher than the silt loam. The loam is slightly higher than the clay, but the very fine sandy loam of the Wabash series is the lowest of all the Wabash types. The Lamoure silty clay is higher than the Lamoure loam. The Cass loam and the very fine sandy loam are similar in organic matter content and both are slightly higher than the silty clay. The silt loam of this series is low in organic carbon, probably due to some abnormal conditions pertaining to this particular sample. The Sarpy silt loam is much higher in organic carbon than the Sarpy very fine sandy loam. In general it would seem that fine-textured soils are richer in organic matter than coarse-textured soils. Silty clay loams are usually higher than silt loams, which in turn are better supplied than loams or sandy loams.

In some cases, the supply of organic matter in the soils of Fremont County is rather low, and additions of fertilizing materials supplying organic matter are very necessary. On the light-colored, coarse-textured soils it is particularly important that the supply of organic matter be increased. Thus the Shelby loam and the Knox silt loam on the uplands are in need of organic matter. The Hancock types on the terraces, the Sarpy soils on the bottoms and the coarse-textured types of the other bottomland series are also in need of fertilizers supplying organic matter. Additions of farm manure are of very large value on these soils. This fertilizer will, however, bring about large increases in crop yields on many of the other types in the county, especially on the Marshall silt loam and the Waukesha silt loam. Small amounts of farm manure may also be used to advantage on the heavier-textured, black soils to stimulate available

TABLE V. PLANT FOOD IN FREMONT COUNTY, IOWA, SOILS
Pounds per acre of 4 million pounds of subsurface soil (6⅔" to 20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
79	Shelby loam	1,912	4,480	44,395	-------	4,000
	LOESS SOILS					
9	Marshall silt loam	2,011	6,027	57,142	-------	3,667
11	Knox silt loam	3,258	2,240	13,300	14,679	None
	TERRACE SOILS					
131	Judson silt loam	4,472	6,640	78,864	-------	4,000
75	Waukesha silt loam	2,208	6,080	57,866	-------	3,000
88	Bremer silt loam	2,712	6,720	71,096	-------	2,000
139	Hancock very fine sandy loam	2,908	3,040	25,384	5,049	None
224	Hancock very fine sandy loam (shallow phase)	2,694	6,720	88,845	-------	2,000
225	Hancock fine sand (shallow phase)	2,478	3,360	28,547	23,211	None
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	3,608	7,440	83,555	-------	4,000
26a	Wabash silt loam (colluvial phase)	3,744	7,520	92,445	-------	3,000
215	Lamoure silty clay	3,314	6,560	69,910	39,769	None
48	Wabash silty clay loam	3,368	7,840	83,391	-------	1,000
216	Cass silty clay	2,640	8,240	29,829	18,820	None
28	Sarpy very fine sandy loam	2,236	2,080	24,097	22,589	None
217	Cass very fine sandy loam	2,882	5,360	46,200	5,340	None
72	Wabash clay	2,478	5,280	48,806	-------	None
192	Wabash very fine sandy loam	3,044	4,240	24,712	-------	None
49	Wabash loam	2,478	5,280	63,648	-------	2,000
18	Cass loam	3,286	6,560	59,120	2,364	None
112	Lamoure loam	3,258	5,120	56,338	7,801	None
106	Cass silt loam	2,640	5,360	57,330	5,554	None
89	Sarpy silt loam	2,720	2,160	38,986	14,681	None

plant food production; large amounts should not be used on these types. Large additions may be made with profit on the light-colored, coarse-textured soils.

Whenever farm manure is not available in sufficient amounts to keep the soils supplied with organic matter, the turning under of leguminous crops as green manures is necessary. Green manuring is a very desirable practice on many of the soils of this county to supplement farm manure. The thoro utilization of all crop residues will also aid in keeping up the supply of organic matter in the soils of the county.

Some of the soils in Fremont County are well supplied with inorganic carbon and have no lime requirement. In a few cases, however, the soils are acid in reaction, show no content of inorganic carbon and are, therefore, in need of lime. The Shelby loam and the Marshall silt loam on the uplands are acid in reaction. The Judson silt loam, Waukesha silt loam and Bremer silt loam on the terraces are also acid in reaction, and the Wabash types on the bottoms show no content of inorganic carbon. In the case of these soil types lime is

needed for the best growth of general farm crops and particularly of legumes. Soils vary widely in lime requirements, hence the figures given in the tables should be considered merely to indicate roughly the amount of lime needed by these various soils. It is very important that the soil in any area be tested for lime needs before an application is made, in order that the proper amount may be applied. If the best crop yields are to be secured on the acid soils in Fremont County, especially for the most satisfactory stands of such legumes as alfalfa and sweet clover, the soil should be tested and lime should be supplied as needed.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4 million pounds of subsurface soil and 6 million pounds of subsoil per acre. These results need not be considered in detail, inasmuch as they bear out the conclusions which have

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

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
79	Shelby loam	2,181	6,380	44,013	-------	4,000
	LOESS SOILS					
9	Marshall silt loam	2,564	7,287	50,913	-------	3,667
11	Knox silt loam	4,647	2,140	5,460	62,115	None
	TERRACE SOILS					
131	Judson silt loam	5,334	9,420	76,410	-------	3,000
75	Waukesha silt loam	3,192	7,820	49,495	-------	3,000
88	Bremer silt loam	2,828	8,860	62,226	-------	2,000
139	Hancock very fine sandy loam	3,918	5,100	44,140	8,627	None
224	Hancock very fine sandy loam (shallow phase)	3,150	8,620	77,801	-------	2,000
225	Hancock fine sand (shallow phase)	3,837	12,620	81,655	9,808	None
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	4,848	11,980	118,056	-------	4,000
26a	Wabash silt loam (colluvial phase)	3,798	8,140	75,510	-------	3,000
215	Lamoure silty clay	4,887	9,100	76,022	12,332	None
48	Wabash silty clay loam	3,312	4,600	62,093	-------	1,000
216	Cass silty clay	3,150	4,940	30,819	38,392	None
28	Sarpy very fine sandy loam	3,354	3,800	33,412	43,816	None
217	Cass very fine sandy loam	3,918	5,100	21,392	44,056	None
72	Wabash clay	3,636	7,820	63,394	-------	None
192	Wabash very fine sandy loam	4,647	10,540	91,146	-------	None
49	Wabash loam	3,273	9,420	77,964	-------	2,000
18	Cass loam	3,513	3,260	16,983	28,012	None
112	Lamoure loam	4,386	6,060	46,741	24,842	None
106	Cass silt loam	3,918	7,500	53,473	21,628	None
89	Sarpy silt loam	3,999	5,420	33,822	43,897	None

been drawn from the analyses of the surface soils. Unless large amounts of plant food constituents occur in the lower soil layers, there is little effect on the fertility of the soil from the plant food present in the subsurface soil and subsoil. There is no large supply of any of the plant food constituents in the lower soil layers in this county, hence the fertility of these soils will not be affected to any considerable extent.

The conclusions drawn, regarding the needs of the soils of the county, in the discussion under the surface soils are confirmed by the analyses of the lower soil layers. The phosphorus supply in the soils is low, and additions of phosphate fertilizers will be needed now or in the immediate future. Tests of rock phosphate and superphosphate are recommended on the individual soils.

Some of the types are low in nitrogen and organic matter, and in these cases applications of farm manure are of particularly large value. The turning under of leguminous green manures would also be of large value, and the thoro utilization of all crop residues would aid in building up the supply of nitrogen and organic matter. On all the types in the county, however, the use of farm manure would prove of profit, and wherever farm manure is not available, green manuring should be practiced. Systems of permanent fertility for this county should include the regular application of fertilizing materials which supply organic matter and nitrogen, if the soils are to be kept satisfactorily productive.

Some of the soil types are acid in reaction and need lime. In general the types which show acidity in the surface soil are acid thruout the soil section. The Marshall, Shelby, Judson, Waukesha, Bremer and Wabash types are generally acid in reaction and in need of lime. These types should be tested, and lime should be applied as necessary for the best growth of general farm crops and particularly of legumes.

GREENHOUSE EXPERIMENTS

One greenhouse experiment was carried out on the Marshall silt loam, the chief soil type in Fremont County. The results secured in the greenhouse experiments on the Marshall silt loam from Crawford County, Harrison County, and Plymouth County, and on the Knox silt loam from Harrison County and Plymouth County are included, inasmuch as the soil types are the same and the conditions are practically identical. The tests carried out in the greenhouse indicate quite definitely the needs of the same soil types in the field.

The fertilizer treatments employed included superphosphate, rock phosphate, limestone, manure and muriate of potash. These materials were applied in the amounts in which they are usually employed in the field and the results are, therefore, indicative of what may be expected on the farms. Manure was added at the rate of 10 tons per acre, lime was applied in an amount sufficient to neutralize the acidity of the soil. The superphosphate was applied at the rate of 250 pounds per acre, the rock phosphate at the rate of one ton per acre, the muriate of potash at the rate of 50 pounds per acre and the complete commercial fertilizer at the rate of 300 pounds per acre.

Wheat and clover were grown, the clover being seeded about one month

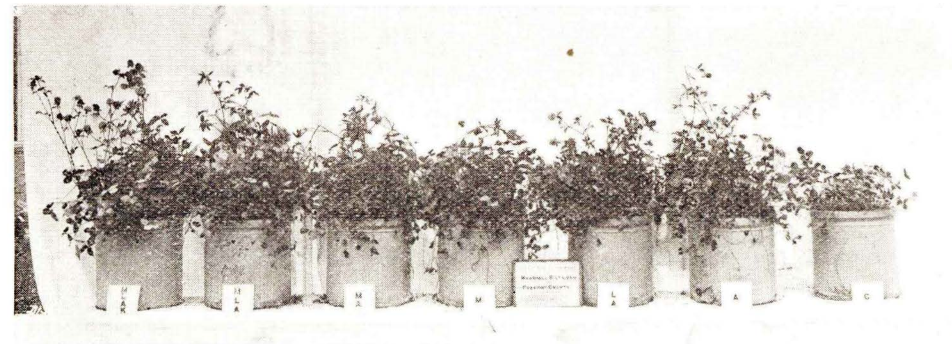


Fig. 3. Clover on Marshall silt loam from Fremont County, greenhouse experiment.

after the wheat was up. In the experiment on the Marshall silt loam from Harrison County only the clover yield was obtained.

THE RESULTS ON THE MARSHALL SILT LOAM

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

These results indicate that this soil type will respond profitably to applications of manure, lime and superphosphate. The use of lime is particularly desirable in connection with the growing of a legume crop, and the addition of superphosphate is strongly recommended. There is no evidence of value from the use of the potash fertilizer.

THE RESULTS ON THE MARSHALL SILT LOAM FROM CRAWORD COUNTY

The results secured in the greenhouse experiment on the Marshall silt loam from Crawford county are given in table VIII. Manure brought about a large

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

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

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

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	8.66	16.16
2	Manure	12.56	30.66
3	Manure+limestone	13.20	38.00
4	Superphosphate	11.70	43.33
5	Manure+superphosphate	11.96	56.83
6	Limestone+superphosphate	12.23	43.50
7	Manure+limestone+superphosphate	14.26	41.66
8	Manure+limestone+superphosphate+potassium	13.25	64.16

increase in the yields of wheat and clover. Limestone with the manure showed a slight effect on the wheat crop and a pronounced influence on the clover. Superphosphate alone had less effect on the wheat than did the manure alone, but it showed a much larger influence on the clover. Manure and superphosphate showed a larger effect than the phosphate alone on the wheat and on the clover. Limestone and superphosphate showed a greater effect on the wheat than the superphosphate alone and about the same influence on the clover. Manure, lime and superphosphate gave the largest increase in the yields of wheat and only a slightly smaller effect on the clover than that brought about by the manure and phosphate without lime. When the muriate of potash was added with the manure, limestone and superphosphate, a smaller effect was brought about on the wheat than without the muriate, but on the clover there was a large increase in the yield.

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

THE RESULTS ON THE MARSHALL SILT LOAM FROM HARRISON COUNTY

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

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

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

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

superphosphate in addition to manure and limestone is apparently very desirable on this soil. Tests of this phosphate fertilizer on individual farms are strongly recommended.

THE RESULTS ON THE KNOX SILT LOAM FROM HARRISON COUNTY

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

On this soil type the effects of manure and superphosphate are clearly shown. The type is low in organic matter and additions of farm manure or the use of leguminous green manures are very desirable.

The use of superphosphate may bring about highly profitable increases in the yields of general farm crops. Tests on individual farms are strongly recommended.

THE RESULTS ON THE MARSHALL SILT LOAM FROM PLYMOUTH COUNTY

The results secured in the greenhouse experiment on the Marshall silt loam from Plymouth County are given in table XI. The superphosphate brought about a large increase in the clover yield, and the limestone with the phosphate gave a further increase. The manure alone gave a large increase in the clover, an effect that was about the same as that brought about by the superphosphate

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

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

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

Pot No.	Treatment	Weight of clover in grams
1	Check	21.1
2	Superphosphate	33.4
3	Limestone+superphosphate	37.8
4	Manure	38.2
5	Manure+superphosphate	40.0
6	Manure+superphosphate+limestone	40.0
7	Manure+superphosphate+limestone+potassium	49.4

and limestone. When superphosphate was added with the manure, however, there was a further gain in the clover yield. The use of limestone with the manure and superphosphate had no further effect. The addition of the muriate of potash with the manure, limestone and superphosphate brought about a considerable increase in the clover.

It is evident from these results that this soil will respond to applications of manure, limestone and a phosphate fertilizer. The liberal use of manure is very desirable; the addition of lime is necessary when the soil is acid; and the use of superphosphate may bring about large crop increases. The application of muriate of potash may be of value in some cases, but tests should be carried out on small areas before applications are made extensively.

THE RESULTS ON THE KNOX SILT LOAM FROM PLYMOUTH COUNTY

The results secured in the experiment on the Knox silt loam from Plymouth County are given in table XII. The superphosphate increased the yield of wheat and brought about an enormous increase in the yield of the clover. Manure alone gave about the same effect as the superphosphate in the case of the wheat but showed less effect on the clover. Superphosphate with the manure brought about a large increase in the case of the wheat and a very large increase in the yield of the clover. When the muriate of potash was added with the manure and superphosphate, the largest increase in the yield of wheat was secured but no effect was evident on the yields of clover.

It is apparent from this test that the Knox silt loam will respond to applications of manure and a phosphate fertilizer in a very profitable way. The use of manure is especially desirable on the type and large increases in the yields of general farm crops may be expected. The application of superphosphate is strongly recommended and it will undoubtedly prove profitable in most cases.

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

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	5.8	7.7
2	Superphosphate	7.1	33.7
3	Manure	7.8	29.1
4	Manure+superphosphate	9.2	51.1
5	Manure+superphosphate+potassium	10.4	42.8

The use of potassium fertilizers may be desirable in individual cases, but tests are recommended before any extensive application of this fertilizing constituent is made.

FIELD EXPERIMENTS

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

These experiments are planned to determine the value of various soil treatments and are laid out on land which is representative of the particular soil type. The fields include 13 plots, 155 feet 7 inches by 29 feet or one-tenth of an acre in size. These are permanently located by the installation of corner stakes, and all precautions are taken in the application of fertilizers and in the harvesting of the crops to insure accurate results.

The fields include tests under the livestock system of farming and under the grain system. In the former manure is applied as the basic treatment, while in the latter crop residues are employed to supply the organic matter. The other fertilizing materials tested include limestone, rock phosphate, superphosphate, muriate of potash and a complete commercial fertilizer. Manure is applied at the rate of 8 tons per acre once in a four-year rotation. The crop residues treatment consists of plowing under the corn stalks which have been cut with a disk or stalk cutter, and plowing under at least the second crop of clover. Sometimes the first crop of clover is cut and allowed to remain on the land to be plowed under with the second. Lime is applied in sufficient amounts to neutralize the acidity of the soil. Rock phosphate is added at the rate of 1,000 pounds per acre once in a four-year rotation. Until 1925 rock phosphate was applied at the rate of 2,000 pounds per acre once in four years. Superphosphate is applied at the rate of 150 pounds per acre annually three years out of a four-year rotation. Until 1923 this material was applied at the rate of 200 pounds per acre annually. Until 1923 the old standard 2-8-2 complete commercial fertilizer was used, being applied at the rate of 300 pounds per acre annually. The new standard 2-12-2 brand is now being employed the applications being made at the rate of 202 pounds per acre annually, thus applying the same amount of phosphorus as is contained in the superphosphate. Muriate of potash is applied at the rate of 50 pounds per acre.

THE RED OAK FIELD

The results secured on the Red Oak Field on the Marshall silt loam in Montgomery County are given in table XIII. Benefits from the application of manure to this soil are shown definitely by the data in this table. The increased yield of winter wheat in 1918 is particularly noteworthy. The corn crops were increased to a large extent in every case, and increases were also noted with

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

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

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

the oats in 1921, the winter wheat in 1922 and 1925, the soybeans in 1924 and the alfalfa in 1927 and 1928. The largest beneficial effects from lime were shown, as would be expected, on the alfalfa in 1927 and 1928, but increases were also secured on the corn crop in 1920, the oats in 1921, the wheat in 1922 and the corn in 1923. The soybeans in 1924 also showed a considerable beneficial effect of the lime.

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

The crop residues treatment had little effect on the crop yields, as would be expected. Lime with the residues usually increased the yields, particularly of the alfalfa in 1928, the soybeans in 1924, the corn in 1920 and the wheat in 1922 and in 1925. The phosphate fertilizers, when applied with the crop residues and lime, increased crop yields in several instances, particularly the

wheat in 1922 and 1925, and the alfalfa in 1927 and 1928. The oats were materially benefited in 1921, and the phosphate increased the wheat yields in 1918. No large beneficial effects of the phosphates were shown on the corn in 1920 or in 1923, but the rock phosphate showed an increase in 1919. The complete commercial fertilizer again had about the same effect as that brought about by the use of the phosphates. In one or two instances the complete fertilizer gave larger effects, as for example on the soybeans in 1924, on the corn in 1923 and on the oats in 1921; but in other cases, as with the alfalfa in 1927 and 1928, and the corn in 1920, the influence of the complete fertilizer was less than that of the phosphates.

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

THE AVOCA FIELD

The results secured on the Marshall silt loam on the Avoca Field in Pottawattamie County are given in table XIV. The beneficial effect of manure on this soil is shown in practically all cases. The influence on the oats may be noted particularly and also the large effects on the clover and sweet clover. The corn yield in 1926 was very largely increased by the addition of manure. In other years the effects on the corn were much smaller. The influence of lime was particularly evident on the sweet clover crop in 1924 on which a very large increase in yield resulted from the application. There was also an effect noted on the oats in 1927. No beneficial effects were shown on the clover crop in 1921.

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

The crop residues treatment generally had a small influence. Lime with the crop residues increased the crop yields, with the exception of the corn crops in 1926 and 1928. The largest influence of the lime was evident on the sweet clover in 1924. Considerable increases were noted, however, on the corn in 1922, on the oats in 1923 and on the corn in 1925. The rock phosphate and the superphosphate brought about increases in crop yields in several cases, the effect of the superphosphate being particularly large on the oats in 1920 and

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

Plot No.	Treatment	(1) 1919 Corn bu. per A.	(2) 1920 Oats bu. per A.	(3) 1921 Clover tons per A.	(4) 1922 Corn bu. per A.	1923 Oats bu. per A.	(5) 1924 Sweet Clover tons per A.	1925 Corn bu. per A.	1926 Corn bu. per A.	1927 Oats bu. per A.	1928 Corn bu. per A.
1	Check	72.9	62.2	2.0	58.1	48.7	0.36	62.2	54.6	45.7	64.5
2	Manure	72.1	69.0	2.7	53.6	56.7	0.63	63.9	63.7	56.0	67.5
3	Manure+lime	74.0	72.3	2.6	53.9	53.2	1.82	61.6	64.0	64.0	68.3
4	Manure+lime+rock phosphate	77.8	58.8	2.7	65.5	60.0	1.52	58.1	61.3	69.8	66.4
5	Manure+lime+superphosphate	79.3	69.0	2.5	56.5	60.0	1.68	52.3	64.8	75.0	70.9
6	Manure+lime+complete commercial fertilizer	77.5	61.2	2.8	57.5	66.8	1.92	51.4	65.6	79.1	65.6
7	Check	71.5	56.8	2.0	44.8	47.6	0.85	39.8	61.0	50.0	64.3
8	Crop residues	78.9	63.9	2.0	44.8	49.8	0.90	51.0	66.4	57.1	66.7
9	Crop residues+lime	80.7	68.1	2.1	50.0	56.7	1.92	58.7	64.5	66.7	66.4
10	Crop residues+lime+rock phosphate	78.5	68.6	2.8	54.8	59.0	1.83	56.8	69.6	66.6	62.1
11	Crop residues+lime+superphosphate	81.1	75.1	2.2	54.1	64.5	1.50	57.1	66.6	64.7	66.1
12	Crop residues+lime+complete commercial fertilizer	80.4	68.6	2.9	52.0	52.1	1.44	58.4	65.8	70.0	64.8
13	Check	80.0	68.6	2.2	46.3	50.9	1.12	51.8	60.8	60.6	61.6

1. Field slopes toward plot 13.
2. Not limed until October 1, 1920. Three tons per acre.
3. Field pastured until June 1.
4. Corn injured by hail in August and by rainy spring.
5. Strong winds and wireworms cut down stand considerably.

in 1923. The effects on the corn crop were not large from either of the phosphates. The complete commercial fertilizer had about the same effect as the superphosphate except on the oats in 1927 where a large influence was noted, and on the clover in 1921 where it brought about a greater effect.

The Marshall silt loam responds very profitably to applications of farm manure, and this material should be applied in liberal amounts to the soil. The type is generally slightly acid in reaction, and additions of lime are desirable, especially where legumes are to be grown. Sweet clover is particularly sensitive to acidity, and an adequate content of lime in the soil is essential for this crop. The type should be tested and the necessary additions should be made if sweet clover or alfalfa are to be grown. Beneficial effects from phosphate fertilizers have been secured both with the manure and lime, and under the grain systems of farming with crop residues and lime. The complete commercial fertilizer generally had no greater effect than the superphosphate and is not recommended for general use. Complete fertilizers will probably prove less economical than superphosphate. Tests of superphosphate, and rock phosphate should be carried out on this soil on individual farms to determine the relative value of the two materials.

THE VILLISCA FIELD

The results secured on the Marshall silt loam on the Villisca Field in Montgomery County are given in table XV. The application of manure increased the crop yields in each year as shown in the table. Large increases were noted on the clover in 1918 and on the corn in 1922. Lime was not applied to this field until the fall of 1920. In the succeeding years the effect of lime was evident on the clover and the corn crop. Evidently the soil was in need of the addition in order to yield the largest crops.

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

Very little influence from the crop residues was evident on the yields of the various crops. Lime applied with the residues brought about increases in the crops in 1921, 1922 and 1923. The differences were definite but not large in any case.

The rock phosphate and superphosphate practically always increased crop yields with the exception of the clover in 1921. The differences were not very large, however, except for the corn in 1919 and the oats in 1920 which were

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

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

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

considerably influenced by the superphosphate while the rock phosphate had little effect. In 1922 and 1923 the superphosphate was slightly better than the rock, but the differences were small in both cases. Neither material had any effect in 1925. The complete commercial fertilizer with the lime and crop residues had a somewhat greater effect than the superphosphate in three or four cases. The differences were not large except on the corn in 1922. It was more effective than the superphosphate on the oats in 1920 and in 1925 but showed less effect than the phosphate on the clover in 1918 and on the corn in 1919.

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

THE CLARINDA FIELD

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

The rock phosphate or superphosphate applied with the manure and lime proved of particularly large value on the clover in 1917. Large increases were also noted on the corn in 1919 and 1923. In some seasons, however, only small increases were secured and in several cases no increases at all were obtained. The complete commercial fertilizer had a greater effect than the superphosphate on the crops grown in several seasons. The difference was particularly evident on the oats in 1920 and in 1924 and on the same crop in 1928. In most instances, however, the superphosphate was just as effective or even more effective than the complete fertilizer.

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

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

Plot No.	Treatment	1915 Corn bu. per A.	1916 Oats bu. per A.	1917 Clover tons per A.	(1) 1918 Corn bu. per A.	1919 Corn bu. per A.	1920 Oats bu. per A.	1921 Soybeans bu. per A.	1922 Corn bu. per A.	1923 Corn bu. per A.	1924 Oats bu. per A.	1925 Clover tons per A.	1926 Corn bu. per A.	1927 Corn bu. per A.	1928 Oats bu. per A.
1	Check	51.2	61.1	1.19	----	55.1	51.0	23.5	79.4	65.9	55.6	1.45	41.0	45.6	61.2
2	Manure	49.9	54.4	1.36	----	58.7	52.3	25.3	87.4	73.7	53.4	1.48	42.6	53.7	52.3
3	Manure+limestone	50.6	63.3	1.56	----	62.6	61.8	25.2	89.6	73.6	61.3	1.53	42.5	55.1	74.9
4	Manure+limestone+rock phosphate	48.2	50.0	2.89	----	69.3	63.6	24.2	87.9	82.1	53.7	1.41	44.4	53.2	77.1
5	Manure+limestone+superphosphate	54.8	52.2	3.40	----	70.9	60.4	24.3	88.3	78.0	56.7	1.31	44.0	53.9	72.6
6	Manure+limestone+complete commercial fertilizer	49.7	50.0	2.55	----	59.7	73.5	23.3	90.8	76.7	66.0	1.41	42.6	53.9	84.0
7	Check	48.0	47.7	1.36	----	56.3	41.8	24.0	82.4	64.6	46.5	1.50	40.9	31.5	61.2
8	Crop residues	45.2	41.1	1.53	----	56.5	55.7	23.0	71.8	53.8	61.4	1.74	41.4	46.4	63.5
9	Crop residues+limestone	51.4	43.3	2.21	----	58.2	58.7	25.8	81.2	48.6	49.0	1.81	43.7	52.3	65.9
10	Crop residues+limestone+rock phosphate	51.6	47.7	2.71	----	66.7	61.1	25.8	85.2	54.5	52.7	1.65	42.9	57.2	70.4
11	Crop residues+limestone+superphosphate	53.4	54.4	2.89	----	69.8	60.4	24.8	87.5	57.2	54.1	1.71	42.5	54.7	68.1
12	Crop residues+limestone+complete commercial fertilizer	50.3	47.7	2.72	----	65.3	62.4	24.8	90.6	70.1	58.8	1.50	41.6	50.9	77.1
13	Check	50.5	47.7	1.36	----	57.2	42.5	22.5	88.7	71.8	43.9	1.49	41.3	45.5	72.6

1. Hot winds seriously damaged corn crop.

clover in 1917 and on the corn in 1923. In other cases the effects of the two materials were quite similar.

The results secured in this field experiment indicate the value of applications of farm manure, lime and a phosphate fertilizer to the Waukesha silt loam. The application of manure is of value and large increases in crop yields will result from its use. Lime should be applied with the manure if the soil is acid and considerable gains in yields of legume crops will follow its application. When applied with manure and lime, superphosphate seemed somewhat superior to rock phosphate in many seasons, but in most instances the differences were small. Either of the two phosphates will prove of value on this soil type under the livestock system of farming. Under the grain system of farming their use is as desirable as on the livestock farm, and here the use of the superphosphate seems somewhat preferable.

The results secured on the Waukesha silt loam on the Clarinda Field, Series 200, are given in table XVII. The beneficial effects of manure are again evidenced on this soil type in practically all seasons and very large increases were secured with the corn in 1920, in 1923 and in 1927. The oats showed a large increase in 1925. In one or two cases no increases were secured with manure, which was undoubtedly due to some abnormal conditions in connection with the crop growth on the manure-treated plots. The addition of lime with the manure gave increases in practically all seasons especially on

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

Plot No.	Treatment	1916 Corn bu. per A.	1917 Oats bu. per A.	(1) 1918 Clover tons per A.	1919 Corn bu. per A.	(2) 1920 Corn bu. per A.	1921 Oats bu. per A.	(3) 1922 Hubam clover tons per A.	1923 Corn bu. per A.	1924 Corn bu. per A.	1925 Oats bu. per A.	(1926) Clover tons per A.	(5) 1927 Corn bu. per A.	(6) 1928 Corn bu. per A.
1	Check	73.1	83.0	1.8	52.2	54 3	49.2	----	70.0	31.2	35.2	1.87	40.9	62.8
2	Manure	77.1	83.0	1.4	56.0	64.4	32.6	----	79.3	41.8	46.6	0.86	60.1	62.3
3	Manure+limestone	78.2	88.0	1.2	57.3	65 0	60.8	----	82.4	44.7	48.5	1.28	63.9	59.8
4	Manure+limestone+ rock phosphate	74.9	91.1	1.8	60.9	65.9	45.8	----	87.4	39.4	47.2	1.64	60.3	67.7
5	Manure+limestone+ superphosphate	75.9	103.6	1.5	64.5	60.9	40.2	----	86.6	40.0	48.8	1.00	62.0	61.3
6	Manure+limestone+ complete commercial fertilizer	80.2	98.0	1.7	61.5	62.2	52.0	----	83.1	28.1	53.7	0.95	50.3	63.6
7	Check	76.7	74.8	2.3	55.0	54.8	43.4	----	79.2	24.4	37.9	1.51	42.1	56.6
8	Crop residues	78.9	73.0	2.0	54.0	58.8	45 6	----	73.8	24.1	39.7	1.55	49.7	58.1
9	Crop residues+limestone	77.5	77.8	1.8	65.7	60.0	44.8	----	69.6	31.7	39.6	1.34	61.2	61.3
10	Crop residues+limestone +rock phosphate	75.8	101.0	1.7	72.7	62.1	53.9	----	70.2	26.2	40.1	1.50	62.8	64.9
11	Crop residues+limestone +superphosphate	76.6	100.3	1.7	72.8	61.1	52.4	----	63.6	26.6	45.2	1.33	57.1	69.9
12	Crop residues+limestone +complete commercial fertilizer	74.4	91.6	1.4	70.8	43.7	54.1	----	69.6	25.4	46.1	1.38	37.6	57.8
13	Check	74.6	68.1	1.3	58.6	44.8	48.4	----	62.8	20.6	36.3	1.12	33.1	50.2

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

the clover in 1926, on the oats in 1917 and 1921. Small gains were secured on practically all of the corn crops.

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

The addition of the complete commercial fertilizer brought about crop increases similar to those occasioned by the use of the phosphates. There does not seem to be any pronounced superiority for the complete commercial fertilizer over the phosphates.

The crop residues increased crop yields to a limited extent in several seasons. The differences, however, were small in every case. Limestone applied with the crop residues brought about increases in several cases. The corn in 1919, 1924 and 1927 showed very large increases from the addition of the lime. Oats were increased also in several seasons.

Rock phosphate or superphosphate applied with the crop residues and limestone greatly increased crop yields in most seasons. The largest beneficial effects were shown on the oats in 1917 altho considerable gains were

noted for this same crop in 1921 and 1925. The corn showed pronounced benefits in 1919 and in 1928, but in general the increases in this crop were not large. There seems no possible choice between these two phosphates under the grain system of farming as the increases in yields were very similar from the use of the two materials. The addition of a complete commercial fertilizer gave crop yields which in most cases were much the same or slightly lower than those brought about by the superphosphate. Certainly there is no evidence from the data to show any superiority for the complete commercial fertilizer over the phosphates.

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

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

The laboratory, greenhouse and field experiments discussed in previous pages have given some general indications regarding the needs of the soils of Fremont County. While the field tests which have been described have been carried out in other counties, the soil types are the same and hence the results may be considered to indicate fairly definitely the effects which may be expected from the same fertilizer treatments on the soils of this county.

While it is not possible to give specific recommendations for the treatment of all the soils, some general recommendations may be made for the handling of the land of the county as a whole. No suggestions are offered except those which have been proved to be of value by considerable practical experience. Any of the recommendations made here may be put into operation on any farm.

In a number of instances it is suggested that tests be carried out under individual farm conditions. Such tests are particularly desirable to determine the field value of phosphate fertilizers and complete commercial fertilizers. It should be understood that such tests may be carried out easily on any farm. Directions which may be followed in conducting simple experiments along these lines are given in Circular 97 of the Iowa Agricultural Experiment Station. Many farmers are testing the value of fertilizing materials on their own soils and are securing data which are not only of considerable value to themselves but are also useful to others who have the same soil types on their farms. The Soils Section of the Iowa Agricultural Experiment Station will aid and advise any farmers who may be interested in carrying out fertilizer tests on their own soils.

Manuring

A number of the soil types in Fremont County are rather poorly supplied with organic matter as is indicated by their light color. On these soils the need of organic matter is evident at the present time, if crop yields are to be most satisfactory. In a few cases the soils are very well supplied and additions are not immediately necessary. In the case of all the soils, however, fertilizing materials supplying organic matter must be applied regularly if the content is to be kept up and the land is to continue satisfactorily productive. On the light-colored, coarse-textured types additions of organic matter in liberal amounts are necessary now.

On the Shelby loam on the drift upland and on the Knox silt loam on the loessial upland, the need for organic matter is evidenced by the light color of the soil. On the terraces the Hancock types are all light in color and sandy in texture and hence are low in organic matter. On the bottoms the Cass and Sarpy soils are more apt to be deficient in organic matter owing to their sandy subsoil conditions. On all these types the application of farm manure is very desirable to increase the supply of organic matter. Large crop increases will follow its use. Its effects will also be beneficial however, on many of the other types in the county. Thus the Marshall silt loam is benefited materially by applications of farm manure. The Judson and Waukesha soils on the terraces are also made more productive by the use of this material. Even on the heavier black soils, like the Bremer, Wabash and Lamoure types, small applications of farm manure are of value in stimulating the production of available plant food. On these latter types large applications of manure should not be made and especially not preceding the grain crop of the rotation as there is danger of causing the crop to lodge. On the light-colored sandy types, however, liberal additions of farm manure are recommended. The ordinary application of manure consists of 8 to 10 tons per acre once in a four-year rotation. It is not always possible to apply this amount of manure to all the land on the farm, but wherever sufficient manure is produced, at least 8 tons should be applied once in every 4 years.

On many livestock farms there is not sufficient manure produced to supply the needs of all the soils, and in such cases green manuring is a very desirable practice. On grain farms green manuring is necessary to maintain the supply of organic matter in the land. When legumes are used for green manures, it is possible to maintain the nitrogen content of the soil as well as the organic matter content. Hence, it is most desirable that legumes be employed for this purpose wherever possible. On the light-colored, coarse-textured types in Fremont County, green manuring would be of particularly large value. The Marshall silt loam would also respond, however, to the treatment. Large effects would undoubtedly be evidenced on the Shelby and Knox soils and on many of the bottomland types. Precautions should always be taken in green manuring, however, as undesirable results may occur if the conditions in the soil do not permit of the proper decomposition of the green material.

The thoro utilization of all crop residues on the farm will aid materially in maintaining the supply of organic matter in the land. These residues should never be burned or otherwise destroyed as their value is large from the fertility standpoint. On livestock farms the residues may be used for feed or bedding and returned to the land with the manure. On the grain farm residues may be applied directly to the soil or stored and permitted to decompose partially before application.

The beneficial effects of manure on some of the important soil types in this county have been indicated in the experiments discussed earlier in this report. The experiences of many farmers bear out the results secured in this connection. There is also considerable evidence in the practical experience of farmers of the value of leguminous crops as green manures. The soils of this county may in general be made more fertile by the proper use of farm manure, leguminous green manures and crop residues.

The Use of Commercial Fertilizers

The soils of Fremont County are generally low in phosphorus and applications of a fertilizing material supplying this element are needed. The bottomland soils are somewhat richer in phosphorus than the upland types, but even these soils have no large supply of phosphorus. Undoubtedly all the soils in the county will need applications of phosphorus fertilizers in the near future, even if they are not of value at the present time. It seems probable, however, from the laboratory, greenhouse and field experiments which have been carried out, that a phosphorus fertilizer might be employed profitably on many of the soils at the present time.

Phosphorus may be supplied to the land in the form of rock phosphate or superphosphate. The latter supplies the element phosphorus in a form available for plant use, but in rock phosphate it is only slowly made available in the soil. The superphosphate is applied annually at the rate of 150 to 200 pounds per acre, while the rock phosphate is applied at the rate of 1,000 to 2,000 pounds per acre once in a four-year rotation. The superphosphate is more expensive but may give quicker returns and because of this fact and the smaller applications may prove more economical.

In the tests which have been reported, both rock phosphate and superphosphate have been employed, in some cases one material proving superior while in other instances the other material seemed preferable. Definite conclusions regarding the relative value of the two phosphates cannot be given at the present time inasmuch as the results will vary widely under different soil and farming conditions. On light-colored sandy soils in which the organic matter supply is low, superphosphate will undoubtedly prove preferable, but on the richer, dark colored, types rock phosphate may be as satisfactory. On such soils farmers are urged to test both materials under their particular conditions and thereby determine the phosphorus needs of their soils, and also which phosphorus carrier may be applied with greater profit.

Some of the soil types in Fremont County are not well supplied with nitrogen, and additions of fertilizing materials supplying this element are necessary for the best crop growth at the present time. On all the soil types in the county nitrogen must be considered when systems of permanent fertility are planned. There is a constant loss of the element from the soil by cropping and by leaching, and some means must be taken to keep up the supply or it will quickly become deficient. Even on those soil types in the county, therefore, which are better supplied with nitrogen at the present time, additions of some fertilizing materials supplying nitrogen will be necessary in the very near future if they are not needed now. The light-colored upland soils and the sandy terrace and bottomland types are particularly in need of nitrogenous fertilizers now. The Shelby loam and the Knox silt loam on the uplands will respond to nitrogen-containing fertilizers, such as farm manure and leguminous green manures. The Hancock soils on the terraces and the Cass and Sarpy types on the bottomlands will also be improved by additions of these fertilizers. Crop yields may be increased considerably on the Marshall silt loam, on the Judson and Waukesha silt loams and on some of the heavier types like the Bremer, Wabash, and Lamoure soils.

The proper preservation and return to the land of all the farm manure produced will aid materially in maintaining the supply of nitrogen in the soil. The proper utilization of all crop residues will also keep up the supply of nitrogen. These valuable natural fertilizing materials should always be thoroly utilized and returned to the land.

The use of leguminous crops as green manures is the cheapest and best means of building up the nitrogen content of the soil. When legumes are inoculated, a large part of the nitrogen contained in the crop is taken from the atmosphere. When the crop is turned under as a green manure, there may, therefore, be a large addition of nitrogen to the land. On all the soil types in Fremont County which are light in color and low in nitrogen, like the Shelby, Knox, Hancock, Cass and Sarpy soils, the use of leguminous green manures is very desirable. On many of the other soils in the county the practice of green manuring may be of large value as a supplement to, or substitute for, farm manure.

For general farm crops, commercial nitrogenous fertilizers are probably unnecessary on the soils of Fremont County at the present time. Undoubtedly the nitrogen supply of these soils may be built up and maintained more economically and satisfactorily by the use of leguminous green manures in addition to the proper application of farm manure and crop residues. Small amounts of nitrogenous fertilizers may sometimes be used with profit as top dressings for special crops but for the ordinary farm crops their use will probably not pay.

It seems very unlikely that potassium fertilizers would prove of value on the soils of this county, inasmuch as analyses have shown a high content of this constituent. The supply of potassium in the soil is certainly adequate to meet the needs of many crops, provided, of course, that it is made available sufficiently rapidly. If the soil is kept in the best physical condition and properly handled, there should be an adequate production of potassium to provide for satisfactory crop yields. Commercial potassium fertilizers cannot be recommended for general use at the present time. Farmers who are interested may test the value of commercial potassium fertilizers by applying them to small areas. Extensive applications should not be made, however, until such tests have been carried out and the economic value of the treatment definitely shown.

In the experiments given earlier in this report, a complete commercial fertilizer was used in comparison with superphosphate and rock phosphate. In some cases somewhat larger increases were secured from the complete fertilizers, but in no cases were there any large differences in the results from the use of these materials and the application of superphosphate. Phosphorus is the element most likely to be deficient in these soils, and hence phosphate fertilizers might be expected to prove more profitable. Complete commercial fertilizers are more expensive than the phosphorus carriers and they must bring about much larger increases in crop yields to prove as economical. The general application of complete fertilizers to the soils of this county cannot be recommended at this time. Farmers who are interested may test the value of any complete brand in comparison with superphosphate but they should not make any extensive application of a complete fertilizer until they have made such a comparison, if they expect to secure the greatest profit from the treatment. There is no objection to the use of a complete fertilizer provided it proves more effective and more profitable than superphosphate. It is entirely a question of economic returns.

Liming

A number of the soil types in Fremont County are acid in reaction and in need of lime. The Shelby loam on the drift uplands, the Marshall silt loam on the loessial uplands, the Judson silt loam, the Waukesha silt loam and the Bremer silt loam on the terraces, and the Wabash soils on the bottomlands, are all acid and the acidity, while not high in the surface soils, extends thruout the 3 foot section. The other soil types in the county are well supplied with lime and some show a very high content of inorganic carbon.

For the best growth of general farm crops, especially for such crops as alfalfa and sweet clover, the acidity of the soil must be corrected by the proper application of lime. The lime requirement determinations given in the tables earlier in this report are merely indicative of the needs of the acid soils of this county. The acidity in soils varies widely, even in soils of the same type from different areas. Lime needs must, therefore, be determined for every individual field. Samples should be taken from each field and tested for lime needs before any addition is made. Only in this way will it be possible to supply the proper amounts of lime. It is very important that the soils of the Shelby, Marshall, Waukesha, Judson, Bremer and Wabash types be tested for acidity and that lime be applied as needed, if the best yields and especially if the best stands of such crops as alfalfa and sweet clover are to be obtained. Farmers may test their own soils for acidity or lime requirement, but it will usually be more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station where it will be tested free of charge and recommendations made regarding treatment.

The large beneficial effects from an application of lime to the acid soils of this county have been shown in the results of the field and greenhouse experiments which have been discussed. The experiences of many farmers have also indicated the value of liming these acid types. The legume crops of the rotation are benefited materially, and large effects are also frequently secured on the general farm crops of the rotation. It is especially desirable that lime be applied to these acid soils for new seedings of such legume crops as alfalfa and sweet clover. Further information regarding the use of lime on soils, losses by leaching and other problems of liming are given in Extension Bulletin 105, of the Iowa Agricultural Extension Service. A list of companies prepared to furnish limestone is also given in this bulletin.

Drainage

The upland soils in Fremont County are generally well drained naturally. The extensive drainage system of the county has been shown on the drainage map given earlier in this report. The larger streams with their tributaries and intermittent drainageways extend into practically all parts of the upland, hence the uplands soils are, on the whole, satisfactorily drained.

On the terraces the Bremer soils are rather poorly drained. The other terrace types, having less heavy subsoils, are usually fairly adequately drained. The bottomland types of the Wabash and Lamoure series are poorly drained, owing to their heavy, impervious subsoils. The Cass and Sarpy types on the bottomland are well drained because of the sandy subsoil conditions. However, the bottomland types are all subject to overflow, occasionally if not regularly. They must be protected from overflow before drainage conditions can be made satisfactory. The straightening and deepening of the natural drainage channels in the bottomlands, will aid in carrying away the excess water and in improving moisture conditions in the soils.

Wherever drainage is inadequate, the installation of tile is very desirable. Land which is too wet will not produce satisfactory crops, and, while the expense of tiling may be considerable, the increased crop yields secured will warrant the outlay. On any of the upland areas in Fremont County, where the soils are wet, tiling will be of value. On the Bremer silt loam on the terraces and possibly in some areas of the other terrace types the installation of tile may be needed. On the heavier bottomland soils, tiling may be of large value after the soils have been protected from overflow.

The Rotation of Crops

The continuous growing of any one crop quickly reduces the fertility of the soil and yields per acre rapidly decline. It is always desirable, therefore, to follow some rotation of crops. Even if the rotation includes crops which are of less market value, the income from the land under a rotation will be much greater than under continuous cropping. This is due to the crop yields being so rapidly reduced that they will soon become unprofitable where continuous cropping is practiced. Farmers in Fremont County should plan to follow a good rotation system, if they expect to secure the best crop yields and to keep their land permanently productive.

No special rotation experiments have been carried out in this county, but there are numerous rotations which have been practiced successfully in other parts of the state, many of which are very satisfactory for average farm conditions. No single rotation can be recommended as superior; almost any rotation will be desirable provided it contains a legume crop and the money

crop. The following rotations, which are in general use, may serve as a basis upon which rotations suitable for Fremont County may be planned.

1. SIX-YEAR ROTATION

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

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

2. FOUR OR FIVE-YEAR ROTATION

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

3. FOUR-YEAR ROTATION WITH ALFALFA

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

4. FOUR-YEAR ROTATIONS

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

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

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

5. THREE-YEAR ROTATIONS

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

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

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

The Prevention of Erosion

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

Erosion occurs to some extent in Fremont County, the Shelby loam on the drift uplands being most seriously affected by this injurious action. The Marshall silt loam is also eroded considerably in some areas and the Knox silt loam likewise suffers in some cases. It is important, therefore, that some means be taken to prevent the washing away of the surface soil of these types and the formation of gullies, if the land is to continue to be satisfactorily productive.

Various methods are followed for the control and prevention of erosion in Iowa. These methods differ somewhat, depending upon the type of erosion. Erosion due to "dead furrows" may be controlled by "plowing in," by "staking in" or by the use of earth dams.

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

INDIVIDUAL SOIL TYPES IN FREMONT COUNTY**

There are 20 individual soil types in Fremont County which with the shallow phase of the Hancock very fine sandy loam, the shallow phase of the Hancock fine sand, the colluvial phase of the Wabash silt loam and the area of Riverwash, make a total of 24 separate soil areas. They are divided into four groups on the basis of their origin and location. These groups are drift soils, loess soils, terrace soils, and swamp and bottomland soils.

Drift Soils

The one drift soil in the county is known as the Shelby loam. It covers 6.8 percent of the total area.

SHELBY LOAM (79)

The Shelby loam is found in numerous small areas separating the Marshall silt loam on the uplands from the bottomland areas along the major streams in the eastern part of the county. It occurs in narrow strips on the slopes to the stream courses. There are no large individual areas of the type. The largest developments of the soil are along the East Nishnabotna River and Hunters, Honey, Mill, Fisher, High and Rock creeks.

The surface soil of the Shelby loam is a dark brown, friable loam, extending to a depth of 5 to 9 inches. The subsurface layer consists of a light brown or yellowish-brown sandy or gritty clay, underlaid at a depth of 16 or 18 inches by a somewhat heavier-textured, lighter-colored clay. Below 40 to 60 inches the unweathered glacial till occurs. It is a gray and brown, mottled brown and rusty brown, compact clay or clay loam.

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

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

There are some variations in the characteristics of the surface soil. On the tops of the hills the soil is almost a silt loam, on the slopes it is a loam and at the base of the slopes it is quite sandy, approaching a sandy loam. The predominating texture of the soil in this county is a loam and it is so mapped; it is quite impossible to separate the areas of the various textures for they are too small. In Page County a similar soil is mapped as the Shelby silt loam. Boulders of varying size occur thruout the soil section and are sometimes found on the surface. Erosion has been active in this soil, and in many cases the underlying yellowish-brown clay subsoil has been exposed. These areas are known locally as "clay hills".

In topography the Shelby loam is rolling to hilly, and drainage is well established to excessive on the steeper slopes. Much of the type is too steep to be cultivated and is utilized for pasture. On the cultivated areas, which are farmed in conjunction with the Marshall silt loam, general farm crops are grown, including corn, oats, wheat and hay. The yields, however, are lower than on the Marshall silt loam.

The Shelby loam is particularly in need of additions of organic matter, if it is to be made more satisfactorily productive. Liberal applications of farm manure are very desirable, and the turning under of leguminous crops as green manures would also improve the fertility conditions in the soil. The type is acid in reaction, and the application of lime is necessary for the best growth of legumes and also of general farm crops. The addition of a phosphate fertilizer would undoubtedly prove of value, and tests of superphosphate are recommended. With proper care in handling this soil, particularly in plowing and cultivating; with the use of organic matter as suggested; and with the application of necessary fertilizing materials the Shelby loam may be made productive, provided it is topographically suitable for cultivation and erosion may be prevented from exerting a serious detrimental effect. On the steeper slopes the type should undoubtedly be left in pasture.

Loess Soils

The two loess soils in the county are classified in the Marshall and Knox series. Together they cover 39.5 percent of the total area.

MARSHALL SILT LOAM (9)

The Marshall silt loam is the largest loess type and the most extensively developed soil in the county. It covers 33.1 percent of the total area. It is found in large areas in all the eastern and central townships and is the chief soil type in all parts of the county, except the extreme western townships which are entirely covered by the bottomland soils along the Missouri River.

The surface soil of the Marshall silt loam is a very dark, grayish-brown, friable silt loam, extending to a depth of about 12 inches. When wet the soil appears almost black. The lower part of the surface layer is slightly heavier than the upper part, the texture remaining very similar to a depth of 24 inches, but the color becomes a lighter grayish-brown toward the lower part of the 24 inch depth. Below 24 inches the subsoil is a brown or yellowish-brown heavy silt loam or silty clay loam to a depth of 30 to 35 inches, changing at this point into a grayish-yellow or yellowish-brown soft structureless silty material. Below

4 to 8 feet the parent loess is reached. This is a grayish silt loam, resembling the surface soil in texture but being much lighter in color. Carbonates are present in this lower layer and often thruout the subsoil. They are rarely found, however, in the surface layer.

There are many variations in the color and depth of the surface soil in different parts of the county. In the rolling plain south of Tabor the soil is dark in color to a depth of 12 to 16 inches, but in areas where erosion has occurred to a greater extent the surface soil has been largely removed and the lighter-colored subsoil has been exposed. On the tops of ridges and on the upper slopes the soil is often a brown to light brown and the surface soil is only 6 or 8 inches in depth. In the eastern part of the county narrow bands of drift material on the slopes have been included with the type, as they are often too small to show on the map. Where such strips are sufficiently wide, they are mapped as Shelby loam.

In topography the Marshall silt loam is gently rolling to rolling and hilly. Between the West Nishnabotna and Missouri rivers the areas are gently rolling. As the uplands approach the streams the land becomes more rolling to hilly. The slopes of the rolling areas are gentle and the ridges are well rounded, but in the hilly sections the slopes are steeper and the ridges are narrow. On the latter areas there is considerable erosion and frequently the surface soil is rapidly carried away. Drainage of the type is generally adequate. Only in a few limited areas is there need for tiling.

About 90 percent of the Marshall silt loam is under cultivation, the remainder being in hay and pasture. In the hillier areas along the creeks and larger streams it is impossible to grow cultivated crops and these areas are largely in tree growth and used for pasture. The tree growth consists of oak, elm, maple, hickory and ash. A few groves of walnut, cottonwood and linden have been planted around farmsteads. Corn is the chief crop and yields average 46 bushels per acre, with a range of 30 to 65 bushels. Wheat yields 15 to 25 bushels per acre. Oats vary widely in yields, depending upon the season and the soil conditions. They average 34 bushels per acre but yields as high as 91 bushels per acre are sometimes secured. Alfalfa, sweet clover, red clover and timothy are the principal hay crops. As many as five cuttings of alfalfa, yielding 4 to 5 tons per acre, are often obtained. The average yield of this crop is 3.8 tons per acre. Alfalfa is considered a very valuable crop on this soil. Sweet clover is a new crop in the county and it is becoming popular, especially as a pasture and green manure crop. Clover and timothy hay usually yields about 2 to 2½ tons per acre. Minor crops grown include rye, barley, sorghum, potatoes and orchard fruits. A few commercial apple orchards are found on this soil.

The Marshall silt loam is naturally a productive soil and crop yields are generally satisfactory. It may be improved in productivity, however, by proper methods of soil treatment. The use of farm manure is very desirable on the soil, and large increases in the yields of farm crops will follow its application. The turning under of legumes as green manures will also prove of value in many cases in improving the soil conditions. The soil is acid in reaction in the surface soil, and the use of lime to remedy this acid condition is necessary for the best growth of legumes, particularly alfalfa and sweet clover. Lime may be of especial value in getting a stand of these crops. The application of a phosphate fertilizer would undoubtedly prove profitable, and tests of rock phosphate and superphosphate are recommended. The experiments reported earlier have shown the large value which may result from the use of these fertilizing materials. Additions of farm manure, lime and a phosphate fertilizer may bring about very considerable increases in the yields of general farm crops.

KNOX SILT LOAM (11)

The Knox silt loam is the second largest loess soil and the fifth most extensively developed type in the county. It covers 6.4 percent of the total area. It occurs entirely in the western part of the county, on the bluffs bordering the Missouri River bottoms, along the lower courses of the Nishnabotna Rivers, and east of Hamburg, just north of the Missouri state line. The largest areas of the type are found on the hilly to steep bluffs along the broad Missouri bottoms.

The surface soil of the Knox silt loam is a grayish-brown or brown friable silt loam, extending to a depth of 4 to 8 inches. The subsurface soil is a brown or yellowish-brown silt loam or heavy silt loam, slightly heavier in texture than the surface soil. Below 18 to 24 inches the subsoil is a grayish-yellow or grayish-brown loose silt loam. The subsoil is highly calcareous and the surface soil is also usually high in lime content. The changes from one layer of soil to another are not abrupt; there is usually a gradual change and the layers are rarely sharply distinguishable. Over the greater part of the soil the dark surface soil is thin and rests directly on the yellow parent loess. In many places the surface soil has been entirely removed by erosion and the yellow or brown silt loam subsoil is exposed.

In topography the Knox silt loam is rough to broken and the slopes are steep and narrow. The land is cut by deep ravines and little of the type is suitable for cultivation. Native timber of oak, elm, hickory, walnut, basswood and ash cover a large part of the soil. In wet seasons the badly eroded slopes support a fair growth of grasses for pasture use, but in dry years the slopes are practically barren. A few of the more gentle slopes, narrow ridges and bases of the slopes are utilized for growing corn, oats and hay. The soil is well suited to alfalfa and sweet clover, largely because of the high lime content. Many of the slopes have been successfully seeded to these legumes and are utilized for pasture purposes. Special crops, such as melons, sweet potatoes and truck crops, are well adapted to this soil and may be grown profitably with proper fertilization and satisfactory marketing conditions. Commercial orcharding might be successful in this soil. One orchard on the type is proving profitable.

Yields of general farm crops on the Knox silt loam are much lower than on the Marshall silt loam and the better types in the county. Much greater yields may be secured by proper methods of soil treatment. The addition of farm manure is very desirable, and liberal amounts of this fertilizing material may be used with large beneficial results. The turning under of legumes as green manures would also prove of value in building up the supply of organic matter in the soil, and in adding nitrogen. The type is low in both of these constituents. The addition of a phosphate fertilizer would also prove of value, and tests of superphosphate are recommended. Where truck crops are grown, the use of a good complete commercial fertilizer would undoubtedly prove profitable. Brands are on the market which may give very desirable effects on individual truck crops. Tests of these materials are very desirable.

Terrace Soils

There are four terrace types in the county, classified in the Judson, Waukesha, Bremer and Hancock series, and these with the shallow phase of the Hancock very fine sandy loam and the shallow phase of the Hancock fine sand make a total of 6 separate terrace soil areas. Together they cover 12.1 percent of the total area.

JUDSON SILT LOAM (131)

The Judson silt loam is the largest terrace type, covering 4.5 percent of the total area. It occurs in numerous areas on the terraces adjacent to the Missouri River bottoms and along the bottomlands of the various streams in other parts of the county. The largest development of the type is along the Missouri bottoms south of Knox and in the vicinity of Thurman. Numerous small areas of the type occur along the Nishnabotna Rivers and their various tributaries and they are found in practically all parts of the county.

The surface soil of the Judson silt loam is a dark brown or almost black, friable silt loam, 18 or 20 inches in depth. The subsoil is similar in texture and color to the surface soil, becoming somewhat lighter in color at the lower depths, ranging from a light brown to a brown.

In topography the Judson silt loam is level to slightly sloping, and drainage is good. The type lies on terraces from 2 to 8 feet below the adjacent uplands. It is not subject to overflow. Practically all of the areas are under cultivation; corn, small grains and hay being grown. On many small areas at the base of the Missouri River bluffs, melons, potatoes and orchard fruits are grown on this type. Three apple orchards located largely on this soil are proving very profitable. On much of the land along the bluffs, corn and small grains are cropped continuously to supply the farm needs as the adjoining rough uplands can be utilized only for pasture.

The Judson silt loam is normally a productive soil, and yields are very much the same as those secured on the Marshall silt loam. It will be benefited, however, by applications of farm manure and the turning under of leguminous crops as green manures. It is acid in reaction, and lime should be applied for the best growth of legumes. It would undoubtedly respond to the application of a phosphate fertilizer, and tests of rock phosphate and superphosphate are recommended.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the second largest terrace type, covering 3.3 percent of the total area. It is developed most extensively along the East and West Nishnabotna Rivers. The largest areas occur in the vicinity of Randolph, Anderson, Hamburg, Farragut and along the Chicago, Burlington and Quincy Railroad between Farragut and Riverton. Several smaller areas have been mapped along the Nishnabotna Rivers, Walnut Creek and Deer Creek.

The surface soil of the Waukesha silt loam is a very dark grayish-brown silt

loam, extending to a depth of about 12 inches. The subsurface soil is a heavy silt loam, dark grayish-brown in the upper part and becoming slightly lighter with depth, extending to about 20 inches. Below this point there is a brown or yellowish-brown heavy silt loam or silty clay loam. Below 30 inches the subsoil is a structureless, friable, heavy silt loam. The type is quite uniform thruout the various areas, but occasionally small patches are found in slight depressions and more level areas where the surface soil is dark-brown or black and extends to a depth of 16 to 24 inches. The subsoil in these areas is a brown, heavy, silty clay loam mottled with gray and rusty brown. One area of this variation is found in Section 16 of Riverside Township. At the edges of the terraces the surface soil is generally somewhat shallower and increases in depth back toward the hills.

In topography the Waukesha silt loam is level to sloping, and drainage is fair to good. The type occurs on terraces well above overflow, lying from 20 to 35 feet above the streams and 8 to 12 feet above the adjacent bottomlands.

Practically all of the Waukesha silt loam is under cultivation and general farm crops are grown. Corn yields from 40 to 70 bushels per acre and hay from 1½ to 3 tons per acre. Some alfalfa and sweet clover are grown on the type and excellent yields of these crops are secured.

While the Waukesha silt loam is considered a highly productive soil, larger crop yields may be secured thru proper soil treatments. It will respond to applications of farm manure, and liberal additions of this material are recommended. The turning under of leguminous crops as green manures would also prove of value. The type is acid and lime should be applied, especially for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly prove profitable, and tests of rock phosphate and superphosphate are recommended.

BREMER SILT LOAM (88)

The Bremer silt loam is the third terrace type, covering 2.5 percent of the total area. It occurs in numerous areas on the terraces along the Nishnabotna Rivers and Walnut Creek. The largest developments of the type are found east of Sidney in sections 16, 17, 20, 21 and 28 of Prairie Township, south of Randolph in Riverside Township, and south of Farragut in Fisher and Riverton townships. There is also a considerable area south of Hamburg and others along the county line north of Randolph. Smaller areas are found along Walnut Creek.

The surface soil of the Bremer silt loam is a very dark grayish-brown or black silt loam, extending to a depth of 8 or 14 inches. The subsurface soil is a light brown, compact silt loam or silty clay loam. The subsoil is a dark drab or grayish-brown, impervious, waxy clay, mottled with brown and rusty-brown. With the type as mapped, small areas of a heavy-textured soil have been included because of their small extent. In these depressed areas the surface soil is a silty clay loam. The largest of these variations occurs in sections 14, 15 and 22 of Riverton Township. Two smaller areas are mapped in sections 16 and 21 of Prairie Township, and another is mapped one-half mile south of Hamburg.

In topography the Bremer silt loam is level to sloping. Drainage is fairly well established but is poor on the level to depressed areas. The type occurs on terraces 10 to 15 feet above the stream channels and from 3 to 6 feet above the flood plains of the streams. It is not subject to overflow.

Practically all of the soil is under cultivation. Corn, oats and wheat are grown on the better drained areas, while the poorly drained sections are utilized for pasture. Corn yields from 40 to 70 bushels per acre, oats from 20 to 45 bushels per acre and wheat from 15 to 35 bushels per acre. Excellent hay yields are secured and on the more poorly drained areas good pastures are maintained.

The first treatment needed by many of the areas of the Bremer silt loam is artificial drainage. Tiling is necessary to remove the excess moisture and, when drainage is accomplished, yields of general farm crops are good. Small applications of farm manure are of value on newly drained areas to stimulate the production of available plant food. The soil is acid in reaction, and lime is necessary for the best growth of legumes. It would undoubtedly respond to the application of a phosphate fertilizer, and tests of rock phosphate and superphosphate are recommended.

HANCOCK VERY FINE SANDY LOAM (139)

The Hancock very fine sandy loam is a minor type in the county, covering less than 1 percent of the total area. It is found on terraces at the base of the Missouri River bluffs, being located where the streams from the adjacent uplands flow into the bottomlands. The most important area of the type is 1½ miles east of the town of Bartlett where the Waubonsie Creek enters the bottomland. Smaller areas are mapped west of Knox, south of Knox, north of Hamburg and south of Thurman.

The surface soil of the Hancock very fine sandy loam is a brown or dark-brown, friable, very fine sandy loam, extending to a depth of 14 or 16 inches. The subsoil is a light brown very fine sandy loam to silt loam. Both the surface soil and the subsoil are calcareous.

In topography the Hancock very fine sandy loam is nearly level, with some slope toward the bottomland. Drainage is good. The terraces lie 4 to 8 feet above the adjacent bottomland and are very rarely flooded.

Practically all of the soil is under cultivation to corn, small grains and alfalfa. Small acreages of melons and other truck crops are grown. Corn yields from 20 to 50 bushels per acre, depending upon seasonal conditions. Oats yield from 15 to 30 bushels per acre, wheat from 10 to 25 bushels per acre and alfalfa from 2½ to 4 tons per acre.

This soil is particularly in need of organic matter to be made more productive. Liberal applications of farm manure would be of value, and the turning under of leguminous crops as green manures would improve the fertility of the soil materially. The use of a phosphate fertilizer would undoubtedly prove of value and tests of superphosphate are recommended. Where truck crops are grown, the use of a complete commercial fertilizer might prove of large value, and tests of a brand prepared for the particular crop are desirable.

HANCOCK VERY FINE SANDY LOAM (SHALLOW PHASE) (224)

This is a minor type, covering less than 1 percent of the total area. It occurs in a number of areas along the bluffs adjacent to the Missouri River bottomland, being developed most extensively south of Thurman, southwest of Knox, north of Hamburg and east of Bartlett.

The surface soil of the shallow phase of the Hancock very fine sandy loam is a yellowish-brown or dark grayish-brown, friable very fine sandy loam 8 or 10 inches in depth. The subsurface soil is a dark-brown or black, heavy, compact silty clay or clay. Below a depth of 20 or 24 inches the subsoil is a dark, drab or grayish-brown, heavy, impervious clay. The surface soil is calcareous and the subsoil slightly calcareous.

Practically all of the area east of Bartlett is under cultivation, but the remaining areas occurring along ditches and in settling basins are utilized mainly as pasture lands. These areas may be farmed successfully in dry seasons but there is always a possibility of flooding and loss of the crop. Corn is the chief crop grown on the area near Bartlett, and yields range from 45 to 65 bushels per acre. Small grains, hay and alfalfa are grown, with very satisfactory yields.

The best use of the areas lying within the settling basins of the ditches is for pasture purposes. For other areas of the type profitable crop yields may be secured with the application of farm manure in liberal amounts, the turning under of leguminous crops as green manures and the application of a phosphate fertilizer. Tests of superphosphate are recommended.

HANCOCK FINE SAND (SHALLOW PHASE) (225)

The Hancock fine sand, shallow phase, is a minor type, covering only 0.3 percent of the total area. It is mapped in two areas, one in Sections 20, 21, 28 and 29, and the smaller in Section 18 of Benton Township.

The surface soil of the shallow phase Hancock fine sand is a yellowish-gray or dark grayish-brown fine sand from 8 to 14 inches in depth. The subsoil is a brown, compact clay stained with rusty-brown. When wet the subsoil appears a chocolate-brown in color. The surface soil, and usually the subsoil, is highly calcareous.

In topography the type is level to slightly undulating. It lies above the surrounding types and well above overflow. It is not drouthy, owing to the heavy subsoil conditions. Most of the soil is cultivated and corn is the chief crop. Yields of 25 to 40 bushels per acre are obtained. Small grains do not do well and are, therefore, grown only to a limited extent. Alfalfa grows well and yields from 2 to 2½ tons per acre.

The type is particularly in need of organic matter to make it satisfactorily productive. Liberal additions of farm manure are very desirable, and the turning under of legumes as green manures would prove of value. The addition of a phosphate fertilizer would undoubtedly prove profitable and tests of superphosphate are recommended.

Swamp and Bottomland Soils

There are 13 swamp and bottomland soils in the county, classified in the Wabash, Lamoure, Cass and Sarpy series. These, with the areas of colluvial phase Wabash silt loam and Riverwash, make a total of 15 separate soil areas. Together they cover 41.6 percent of the total area.

WABASH SILT LOAM (26)

The Wabash silt loam is the most extensive bottomland soil and with the colluvial phase, is the second largest type in the county. The typical Wabash silt loam covers 8.9 percent of the total area. It occurs on the bottomlands along practically all the streams in the county. Wide areas are found along the East and West Nishnabotna Rivers and along Walnut, Deer, Honey and Mill creeks. Numerous isolated areas occur on the Missouri River bottomlands. The most important area of the soil along the Missouri River is found west of Thurman where Plum Creek enters the bottomlands. The soil is also mapped extensively along the smaller intermittent streams thruout the uplands.

The surface soil of the Wabash silt loam is a dark grayish-brown to almost black silt loam, extending to a depth of 14 to 20 inches. The subsoil is a light-brown or grayish-brown, heavy to impervious, silty clay or clay. Black and rusty-brown iron stains are found thruout the lower subsoil. In the lower, poorly drained areas the surface soil is darker, as a rule, and is deeper. In the large areas along Walnut Creek and the Nishnabotna River, the surface soil is brown or dark-brown, and the subsoil is gray and drab, mottled with brown and rusty-brown.

In topography the Wabash silt loam is level to sloping and, with the exception of a few of the more level areas, the soil is fairly well drained. Altho it is a first bottom soil, it is not subject to overflow except in abnormal seasons. The stream channels have been straightened and deepened and rarely do the streams flood the type.

About 75 percent of the type is under cultivation, the remainder being in pasture and timber. The timber growth consists of elm, cottonwood, ash, maple, walnut and willow. Corn is the most important crop and yields 40 to 90 bushels per acre. Oats yield from 25 to 50 bushels per acre but they are apt to lodge and are not grown very extensively. Wheat yields from 20 to 40 bushels per acre. This crop is grown successfully on the higher-lying areas on the Missouri River bottoms, where there is little danger of overflow. Excellent yields of hay crops are secured, and the soil supports a good growth of bluegrass on the areas utilized for pasture.

The Wabash silt loam is naturally a productive soil and when not overflowed will give good crop yields. Some areas are in need of drainage and tiling is necessary before cultivated crops are successfully produced. Small applications of farm manure would be of value in stimulating the production of available plant food. The type is acid and lime is needed for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly prove of value, and tests of rock phosphate and superphosphate are desirable.

WABASH SILT LOAM (COLLUVIAL PHASE) (26a)

The colluvial phase of the Wabash silt loam is the third largest bottomland soil covering 6.4 percent of the total area. It occurs in many narrow strips along the various creeks and minor streams in the county. It is most extensively developed along the smaller tributaries and intermittent drainageways and is found thruout the uplands along these drainageways. There are no large areas of the type.

The surface soil of the type is a very dark grayish-brown or black mellow silt loam, extending to a depth of 18 or 20 inches. The subsoil is a very dark brown or black, waxy, heavy clay loam. There are many variations in the soil as mapped, owing to the continuous deposition on the surface of soil washed down from the adjacent uplands. Many of these variations might be classed with one or the other of the typical soils of the Wabash or Judson series. The entire areas covered, however, are so narrow that it is impossible to separate the various soils contained within them. From the outer edge of these strips there are first narrow areas of the colluvial phase Wabash silt loam; then areas of the Wabash silt loam; and, finally, near the streams, Wabash silty clay loam or Wabash clay. The predominant texture, however, is a silt loam, and hence all the variations are included within the colluvial phase of the Wabash silt loam. There are variations also in the subsoil, according to the nature of the soil buried by the silt loam washed down from the upland, but the greater part of the type has a heavy black clay subsoil. On the higher slopes the silt loam surface soil thins out and the heavy subsoils are exposed.

In the better drained areas and along the outer edges of the wet areas, the soil is farmed with the Marshall silt loam. The poorly drained strips are allowed to remain in grass and are used as pasture land. The chief need of this soil, to be satisfactorily cropped, is for adequate drainage. Small applications of farm manure would stimulate the production of available plant food. The type is acid and in need of lime, if legumes are to be grown. Applications of a phosphate fertilizer would undoubtedly be of value, and tests of superphosphate are recommended.

LAMOURE SILTY CLAY (215)

The Lamoure silty clay is the second largest bottomland soil covering 6.9 percent of the total area. It occurs in very extensive areas on the Missouri River bottomland, the largest extending from west of Thurman in a general southeasterly direction in a more or less continuous area, widening out considerably south of Knox and narrowing toward the county line near Hamburg. Numerous small areas of the type are found in other parts of the Missouri bottoms and also along the East and West Nishnabotna Rivers.

The surface soil of the Lamoure silty clay is a very dark grayish-brown or black, sticky, silty clay, underlaid at a depth of 12 to 15 inches by a compact, sticky, impervious clay, dark-drab or slate-gray, mottled with gray and brown. Both the surface soil and the subsoil are highly calcareous. Where the type occurs adjacent to the Wabash soils there is a more or less gradual transition from one type to the other, and the boundaries are frequently placed rather arbitrarily. In the area along the Mills County boundary, the Lamoure silty clay loam mapped in that county is not continued in Fremont County because of its small extent but is included with the Lamoure silty clay. Small unimportant areas of lighter-textured soils are included with this type. These variations are found on slight elevations in the bottomlands and are less than 5 acres in extent. The subsoil varies in color depending upon the lime content. Where there is a large amount of lime the color is a light gray or slate gray, while in other areas the color is a dark-gray or drab.

In topography the Lamoure silty clay is level and natural drainage is poor. Open ditches and tile drains have been established thruout the level bottomlands and many hundred acres of fertile land have been reclaimed. About 75 percent of the total acreage is under cultivation. The remainder is poorly drained, unsuitable for cultivation and supports a heavy growth of wild grasses. Large acreages are utilized as pasture land. Corn and winter wheat are the most important crops; yields of corn averaging 36 bushels per acre and ranging from 30 to 50 bushels per acre. Wheat yields from 20 to 38 bushels per acre. Under very favorable conditions much higher yields are frequently secured. Oats yield from 20 to 35 bushels per acre. Alfalfa yields from 2½ to 4 tons per acre and wild hay from 1 to 3 tons per acre. Some rye and some barley are grown.

The Lamoure silty clay is a productive soil, when well drained. Until adequate drainage is brought about crops will be poor and in areas which are too wet tiling is necessary. The type requires special attention in plowing and cultivating in order to put the soil in the best physical condition. Fall plowing is considered preferable in that the alternate freezing and thawing during the winter months will break up the clods which are formed. It is very important that moisture conditions be right when the soil is plowed or cultivated, to prevent puddling and clodding. Small applications of farm manure would be of value in stimulating the production of available plant food. The use of a phosphate fertilizer might prove profitable, and tests of rock phosphate and superphosphate are recommended.

WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is the fourth largest bottomland type, covering 4.4 percent of the total area. It occurs on the first bottoms along the East and West Nishnabotna Rivers, in a few isolated spots on the Missouri River bottoms and along Walnut Creek in the northeastern part of the county. The largest development of the type is along the West Nishnabotna River, southwest, west and northwest of Riverton, northwest of Sidney, north of Randolph and northeast of Farragut along the East Nishnabotna River.

The surface soil of the Wabash silty clay loam is a dark-brown or black sticky silty clay, from 10 to 16 inches in depth. The subsoil is a heavy, impervious, waxy clay, dark-drab or grayish-black, mottled with brown and rusty-brown. Iron concretions are found in the lower part of the subsoil. In small depressions, areas of a heavier-textured soil have been included with the type, as they are too small to be included on the map.

In topography the Wabash silty clay loam is level or slightly depressed and the natural drainage is poor. Water stands on the land for long periods following rains. Until it is properly drained, the soil is unsuitable for cultivation. On the undrained portions wild grasses grow and are cut for hay. When adequate drainage is provided, general farm crops are grown successfully, as the soil is naturally rich and fertile. Corn yields from 50 to 95

bushels per acre and wheat from 20 to 38 bushels per acre. Some hay is grown in addition to the wild hay on the undrained areas.

The first treatment needed by this soil is for adequate drainage. When this is accomplished, small amounts of farm manure would prove of value in stimulating the production of available plant food. The type is acid and lime must be applied if legumes are to be grown. The addition of a phosphate fertilizer would undoubtedly prove profitable, and tests of rock phosphate and superphosphate are urged.

CASS SILTY CLAY (216)

The Cass silty clay is the fifth largest bottomland soil, covering 3.6 percent of the total area. It is found entirely in the Missouri River bottoms in association with the Lamoure and Wabash soils. The largest areas are south of Bartlett, near Percival and west of Hamburg. Numerous small areas have been mapped thruout the bottoms.

The surface soil of the Cass silty clay is a very dark brown or black, stiff, waxy silty clay, extending to a depth of 8 or 12 inches. The subsurface soil consists of a layer of silt, sand and clay in varying proportions, grayish or yellowish-brown in color, mottled with brown, rusty-brown and black. This layer usually extends to a depth of 18 to 24 inches. Below that point the subsoil is a yellow and gray fine sand.

There are many variations in the soil in the different areas. The depth of the surface soil varies from 6 inches along the Missouri state line west of Hamburg to 18 inches in the large area near Percival. The large area west of Hamburg includes a variation in which the soil is a dark-brown, silty clay from 10 to 14 inches deep, underlaid by pure sand to a depth of 32 to 34 inches where it rests on a gray calcareous clay loam or clay. This area has been mapped with the Cass silty clay because of its small extent and its similarity to this type.

The topography of the Cass silty clay is level to depressed. The natural drainage of the subsoil is good, but the surface soil is heavy and impervious and percolation is very slow. The soil occurs in old, abandoned channels of the river and hence in many cases it receives the water from the surrounding areas and is apt to be covered with water for long periods. Some of the areas are farmed without artificial drainage, but the large areas are drained by open ditches. Only in extremely wet seasons are crops damaged by excessive moisture. The type is not subject to overflow except in abnormal seasons.

Except for the extremely low areas and small patches of cottonwood, willow and elm, the type is utilized for general farm crops. Corn and winter wheat are grown most commonly. Corn yields from 40 to 65 bushels per acre, wheat from 15 to 30 bushels per acre. Some oats are grown, yielding from 25 to 40 bushels per acre. Alfalfa is produced to some extent and yields 2½ to 4 tons per acre.

The Cass silty clay is chiefly in need of drainage for good crop production. It must be worked carefully to prevent puddling and clodding. It must not be plowed too wet nor yet when too dry. Fall plowing is very desirable to expose the soil to the alternate freezing and thawing of the winter months. Small applications of farm manure would prove of value in stimulating the production of available plant food. The use of a phosphate fertilizer would undoubtedly prove of value, and tests of superphosphate are recommended.

SARPY VERY FINE SANDY LOAM (28)

The Sarpy very fine sandy loam is the sixth largest bottomland soil, covering 2.6 percent of the total area. It occurs entirely on the bottoms along the Missouri River, in numerous areas varying widely in size. The most extensive development of the type is in Benton Township.

The surface soil of the Sarpy very fine sandy loam is a gray or yellowish-gray very fine sandy loam. The subsoil is a yellowish-gray fine sand. Both the surface soil and subsoil are highly calcareous. Included with the areas of the type as mapped are small patches of recently deposited alluvial material. This alluvial material is distinctly variable. Beneath the sandy surface layer is a layer of silt and clay, sometimes exceeding 1½ inches in thickness and occurring at different depths.

The type is level to gently undulating in topography and drainage is good to excessive. About 50 percent of the soil is under cultivation, the remainder being in timber and pasture land. The tree growth includes ash, elm, birch, oak, basswood, cottonwood and willow. Corn, oats and alfalfa, are the chief crops grown on the cultivated area and very satisfactory yields are secured in favorable seasons. Corn yields from 25 to 40 bushels per acre, oats from 20 to 35 bushels per acre, and alfalfa from 3 to 4½ tons per acre. In dry seasons crops are apt to suffer from a lack of moisture.

The chief need of this soil is for the incorporation of organic matter. Liberal applications of farm manure would be of value and the turning under of leguminous crops as green manures would also increase crop yields and lessen the danger of injury in dry seasons. The use of a phosphate fertilizer would undoubtedly prove of value, and tests of superphosphate are recommended.

RIVERWASH (53)

The area of Riverwash in the county amounts to 2.5 percent of the total area. It is mapped in narrow strips along the Nishnabotna Rivers and in larger areas on the bottomlands adjacent to the Missouri River.

Riverwash consists of a mixture of silt, sand and clay and is subject to change after each overflow. Sand bars are formed and are moved by the action of the current, and large areas of land forming the banks of the stream are constantly caving in and being carried away by the river.

The older sand bars are covered with a heavy growth of weeds and small willows. In some areas the trees are from 5 to 10 years old. Areas mapped as Meadow in Mills County are included with the Riverwash in this county. Riverwash has no agricultural value and cannot be farmed or made productive.

CASS VERY FINE SANDY LOAM (217)

The Cass very fine sandy loam is a minor type in the county, covering 1.8 percent of the total area. It is found only on the Missouri River bottoms, being mapped in numerous areas thruout the western townships. The most extensive development of the type is in the southwestern corner of the county. The largest area is near Payne.

The surface soil of the Cass very fine sandy loam is a dark-brown, loose very fine sandy loam, extending to a depth of 8 or 10 inches. The subsurface soil is a mixed light-brown sand and silt from 6 to 12 inches thick. The subsoil below a depth of 20 to 24 inches consists of a loose grayish-brown or yellow fine sand. Both the surface soil and subsoil are calcareous. With the type as mapped there are small areas of a sand or loamy fine sand occurring on the tops of knolls or ridges. These areas are too small to map separately.

In topography the Cass very fine sandy loam is hummocky or billowy. The soil lies several feet above the heavier Wabash and Lamoure types and this, together with its sandy character, insures good drainage. The type, however, is not drouthy.

Practically all of the soil is under cultivation or supports a good growth of pasture grasses. The tree growth consists of a few scattered oak, cottonwood, elm, ash, birch and willow trees. The tree growth is heavier on the areas close to the river. Corn, oats, wheat and alfalfa are the chief crops. Corn yields from 20 to 50 bushels per acre, wheat from 12 to 25 bushels, oats from 20 to 35 bushels and alfalfa from 3 to 5 tons per acre. Melons, potatoes and truck crops are raised on small acreages.

This soil needs chiefly organic matter to make it more productive. Liberal applications of farm manure would be of value, and the turning under of leguminous green manures would also improve the productive power of the soil. The use of a phosphate fertilizer would be of value, and tests of superphosphate are recommended. Where truck crops are grown, a good complete commercial fertilizer might prove profitable.

WABASH CLAY (72)

The Wabash clay, a minor type, covers 1.5 percent of the total area. It is found only on the Missouri River bottoms in close association with the Lamoure silty clay. There are numerous areas of the type scattered thruout the bottomlands, the largest occurring east of Percival, and southwest, west and northwest of Thurman.

The surface soil of the Wabash clay is a very dark brown to black clay, 8 or 10 inches in depth. The subsoil is a heavy, impervious, waxy clay, dark gray or drab, mottled with brown and rusty-brown. The type is level to depressed in topography and natural drainage is poor.

Much of the type is poorly drained and unsuitable for cultivation. These wet areas are utilized as hay land. The yield of wild hay is considerable. Where drainage conditions are adequate, corn and winter wheat are grown. Yields of corn range from 50 to 90 bushels per acre and of wheat from 20 to 38 bushels per acre.

This soil is chiefly in need of adequate drainage to be made more productive. Small amounts of farm manure would be of value in stimulating the production of available plant food. The type is acid and in need of lime if legumes are to be grown. The use of a phosphate fertilizer would undoubtedly prove of value, and tests of superphosphate are recommended.

WABASH VERY FINE SANDY LOAM (192)

The Wabash very fine sandy loam is a minor type in the county, covering 0.9

percent of the total area. It is mapped in a number of small areas on the Missouri River bottoms and along the Nishnabotna Rivers. The most important areas are found northwest of Hamburg, west of Randolph, north of McPaul, southwest of Thurman and in the area surrounding the village of Payne.

The surface soil of the Wabash very fine sandy loam is a dark grayish-brown friable very fine sandy loam, extending to a depth of 18 to 20 inches. The subsoil is a brown and gray mottled clay loam, very compact and waxy in texture. In some of the areas on the Missouri River bottoms, the subsoil is very similar in color and texture to the surface soil. Within areas of the type as mapped there are small patches of soil having a sandy subsoil. If sufficient in size, these areas would have been mapped as Cass very fine sandy loam.

In topography the soil is undulating or hummocky, and natural drainage is good. The type is not drouthy. Practically all of the soil in the Missouri River bottoms is under cultivation, and general farm crops are grown. These areas are not subject to overflow. The land along the Nishnabotna Rivers is subject to overflow and is utilized mainly for pasture. There is a sparse growth of timber, consisting of cottonwood, elm and willow, on some of the areas used as pasture land. On the cultivated areas corn, oats and hay are the chief crops. Corn yields from 25 to 45 bushels per acre, oats from 20 to 40 bushels per acre and hay from 1 to 2 tons per acre.

The chief need of this soil is for organic matter, and liberal additions of farm manure would prove of large value. The turning under of leguminous crops as green manures would also help. The soil is acid in reaction and in need of lime, especially for the growth of legumes. The use of a phosphate fertilizer would undoubtedly prove of value, and tests of superphosphate are recommended.

WABASH LOAM (49)

The Wabash loam is a minor type, covering 0.6 percent of the total area. With the exception of one small area in Section 8 of Riverton Township, along the West Nishnabotna River, it occurs only on the Missouri River bottoms. The largest area is in Section 9 of Benton Township. Two smaller areas are mapped northeast and southeast of Payne.

The surface soil of the Wabash loam is a dark-brown friable loam, extending to a depth of 6 to 10 inches. The subsurface soil is a brown or grayish-brown silty clay loam containing some iron stains. The subsoil is a heavy, waxy, clay loam or clay, dark-drab in color, mottled with gray, brown, rusty-brown and yellow.

In topography the Wabash loam is level to slightly undulating and drainage is good. The soil is not drouthy. About 90 percent of the type is cultivated, and corn, oats, wheat and hay are grown. Crop yields are fairly satisfactory, being somewhat larger than those secured on the Wabash very fine sandy loam.

This soil needs organic matter, and liberal additions of farm manure would prove of large value. The turning under of leguminous crops as green manures would also improve the producing power of the soil. The type is acid and in need of lime for the best growth of legumes. The use of a phosphate fertilizer would undoubtedly prove of value, and tests of superphosphate are recommended.

CASS LOAM (18)

The Cass loam is a minor type, covering 0.6 percent of the total area. It occurs in the Missouri River bottoms. There are no large areas of the type but it is found in a number of small areas chiefly in Benton, Scott, and Sidney townships.

The surface soil of the Cass loam is a dark grayish-brown friable loam, 8 to 10 inches in depth. The subsoil is a mottled gray, yellow and brown, fine sand. Both the surface soil and subsoil are calcareous. In many places the subsoil contains a mixture of sand and silt deposited in layers 2 inches or less in thickness. The surface of the soil is smooth or slightly undulating. The areas are 4 to 6 feet above the surrounding soils and are well drained.

Practically all of the type is under cultivation and general farm crops are grown. Yields are very similar to those secured on the Cass very fine sandy loam. Alfalfa grows well on the soil and is an important crop.

The chief need of the Cass loam is for additions of fertilizing materials supplying organic matter, and liberal amounts of farm manure may be applied with profit. The turning under of legumes as green manures would also prove of value. The use of a phosphate fertilizer would undoubtedly prove profitable, and tests of superphosphate are recommended.

LAMOURE LOAM (112)

The Lamoure loam is a minor type, covering 0.5 percent of the total area. It occurs in the Missouri River bottoms in a number of small areas located east and south of Payne, and west of Percival.

The surface soil of the Lamoure loam is a dark grayish-brown friable loam, extending to a depth of 5 to 8 inches. The subsurface soil is a light-brown or grayish-brown heavy silt loam or silty clay loam. The lower part of the subsoil is a mottled gray, yellow and brown compact clay loam or clay. Both the surface soil and the subsoil are highly calcareous. On the outer edges of the areas of the type the soil is very silty but, owing to the small extent of this variation, the soil is all mapped as the loam. The type is level to slightly undulating in topography and drainage is well established.

The Lamoure loam is all under cultivation, general farm crops being grown. Corn, oats, wheat and alfalfa are the chief crops and their yields are very satisfactory. Applications of farm manure would prove of value, however, for increasing crops. The application of a phosphate fertilizer would undoubtedly prove profitable, and tests of superphosphate are recommended.

CASS SILT LOAM (106)

The Cass silt loam is a minor type, covering 0.2 percent of the total area. It occurs in a few small areas on the Missouri River bottoms. Four small areas have been mapped along the county line north of Bartlett, and one west, three north and one northeast of Percival.

The surface soil of the Cass silt loam is a dark grayish-brown, smooth silt loam, extending to a depth of 6 to 10 inches. The subsoil is an open, porous, yellow and gray sand. The surface soil and subsoil are calcareous.

Practically all of the type is under cultivation and general farm crops are grown. Corn, oats and hay yield about the same as on the Cass loam. Treatments which are of value on the soil include the use of farm manure, the turning under of legumes as green manures and, possibly, the application of superphosphate.

SARPY SILT LOAM (89)

The Sarpy silt loam is a minor type, covering 0.2 percent of the total area. It occurs on the Missouri River bottoms in six small areas adjacent to the Sarpy very fine sandy loam and the Cass silty clay. The areas are located ¾ of a mile west and 2½ miles southwest of Bartlett; 1½ miles west of Wabonsie Lake; along the highway north of the Chicago, Burlington and Quincy Railroad bridge across the Missouri River at Nebraska City; and in the southwestern corner of the county near Hamburg.

The surface soil of the Sarpy silt loam is a light-gray silt loam to a depth of 6 or 8 inches. It contains some very fine sand. The subsoil is a gray and yellow mottled sand.

Much of the soil is in timber or a heavy growth of small willows, and less than 25 percent is under cultivation. Alfalfa is the chief crop, and some corn and wheat are produced. The yields are somewhat higher than on the sandy types of the Sarpy series, and there is little danger of injury from drouth. The soil will respond to applications of farm manure, and liberal additions of this material should be made. The turning under of legumes as green manures would also be of value. The application of a phosphate fertilizer would undoubtedly prove profitable, and tests of superphosphate are recommended.

APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

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

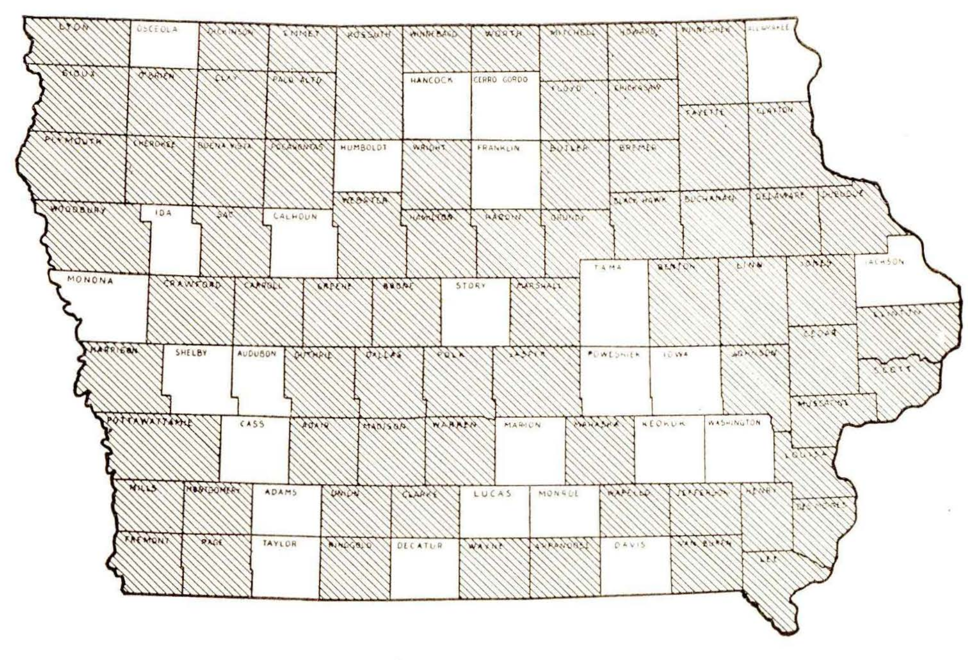


Fig. 4. Map of Iowa showing the counties surveyed.

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

PLANT FOOD IN SOILS

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

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

THE "SOIL DERIVED" ELEMENTS

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

AVAILABLE AND UNAVAILABLE PLANT FOOD

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

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

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

REMOVAL OF PLANT FOOD BY CROPS

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

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

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

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

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNo_3$)), Phosphorus (P) at 12c (Superphosphate), and Potassium (K) at 6c (Potassium Chloride (KCl)).

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	-------	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	-------	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	-------	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	-------	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	-------	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17 00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5.40	16 40

reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

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

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

REMOVAL FROM IOWA SOILS

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

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

PERMANENT FERTILITY IN IOWA SOILS

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

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

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

CULTIVATION AND DRAINAGE

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

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

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

THE ROTATION OF CROPS

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

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

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

MANURING

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

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

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

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

THE USE OF PHOSPHORUS

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

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

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

LIMING

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

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

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 8.

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

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

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

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

THE SOIL SURVEY BY COUNTIES

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

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

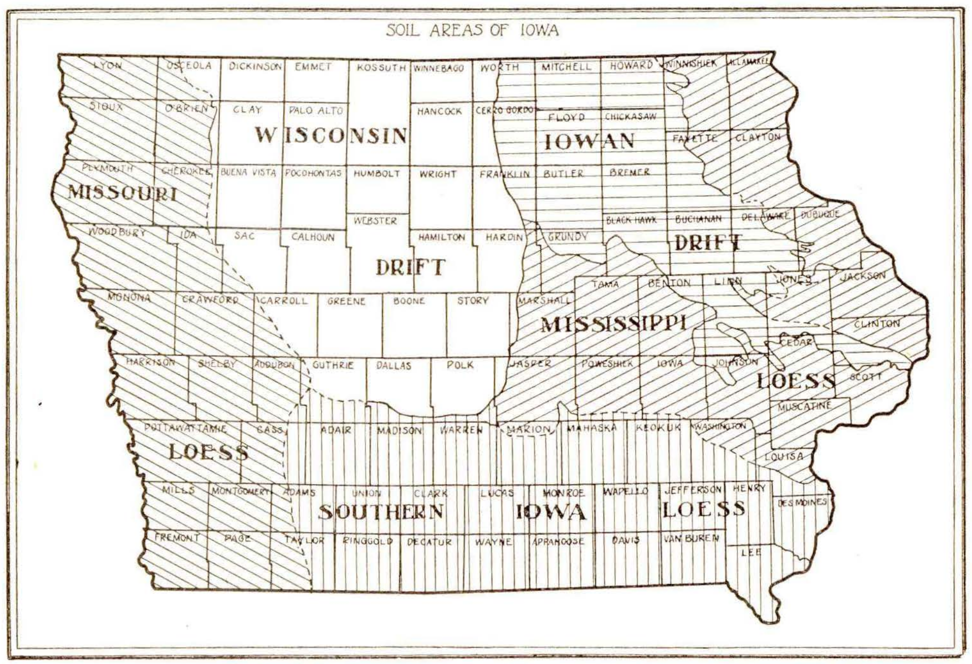


Fig. 5. Map showing the principal soil areas in Iowa.

GENERAL SOIL CHARACTERISTICS

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

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

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

The common soil constituents may be given as follows:†

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

SOILS GROUPED BY TYPES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Gravels—More than 50 per cent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

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

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

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

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

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

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

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

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

IOWA AGRICULTURAL EXPERIMENT STATION

PUBLICATIONS DEALING WITH SOIL INVESTIGATIONS IN IOWA

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

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82 The Principal Soil Areas of Iowa.*
95 The Maintenance of Fertility with Special Reference to the Missouri Loess.*
98 Clover Growing on the Loess and Till Soils of Southern Iowa.*
119 The Gumbo Soils of Iowa.*
124 A Centrifugal Method for the Determination of Humus.*
150 The Fertility in Iowa Soils.*
150 The Fertility in Iowa Soils (Popular Edition).
151 Soil Acidity and the Liming of Iowa Soils.*
151 Soil Acidity and the Liming of Iowa Soils (Abridged).*
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CIRCULARS

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5 Bacteriological Studies of Field Soils, I.*
6 Bacteriological Studies of Field Soils, II.*
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114 Soybean Inoculation Studies.