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SOIL SURVEY OF IOWA

DUBUQUE COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section

Soils

Iowa
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Soil Survey Report No. 35

September, 1924

Ames, Iowa

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September, 1924 Soil Survey Report No. 35

SOIL SURVEY OF IOWA

Report No. 35--DUBUQUE COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of C. L. Orrben,
L. W. Forman, J. L. Boatman and W. G. Baker

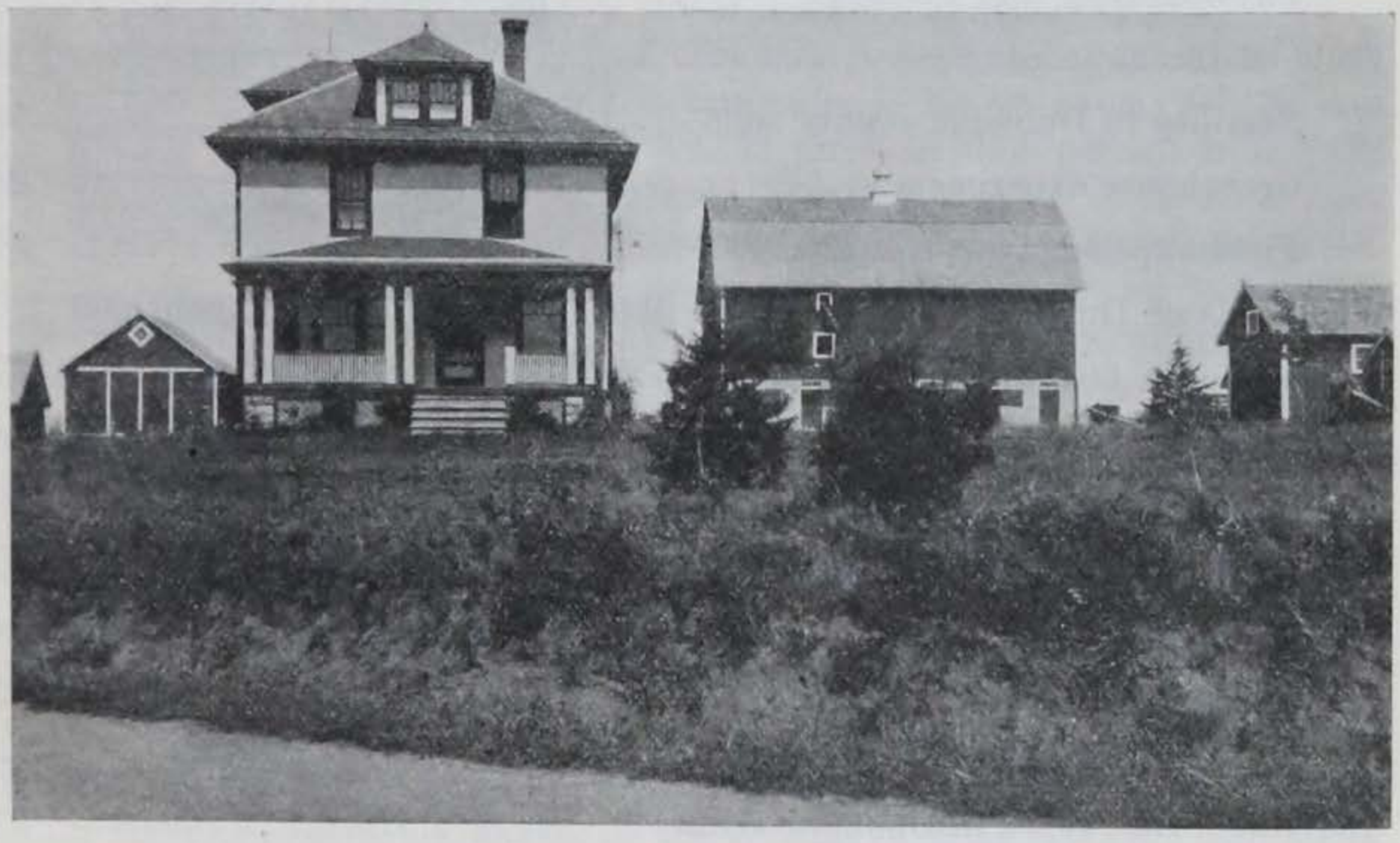

Fig. 1. A typical farmstead in Dubuque county.

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CONTENTS

DUBUQUE COUNTY SOILS*

By W. H. Stevenson and P. E. Brown with the assistance of C. L. Orrben, L. W. Forman, J. L. Boatman and W. G. Baker

DUBUQUE county is located in northeastern Iowa along the Mississippi river, being in the second tier of counties south of the Minnesota state line and adjoining Wisconsin and Illinois on the east. The location is shown in the accompanying sketch map. It lies partly in the Mississippi loess and partly in the Iowan drift soil area and hence its soils are of loessial and glacial origin.

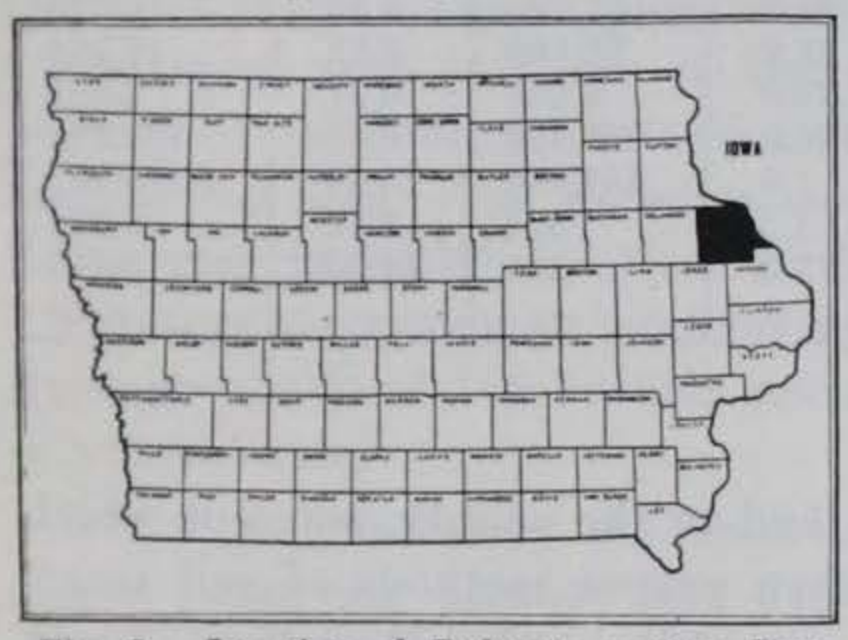

Fig. 2. Location of Dubuque county, Iowa.

The total area of Dubuque county is 601 square miles or 384,640 acres. Of this area 362,152 acres, or 94.1 percent is in farm land. The total number of farms is 2,462 and the average size of the farms is 147 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1922 show the utilization of the farm land of the county:

Acreage in general farm crops	191,450
Acreage in pasture	150,000
Acreage in farm buildings, feed lots and public highways	10,725
Acreage in waste land	8,926
Acreage in crops not otherwise listed	1,286

THE TYPE OF AGRICULTURE IN DUBUQUE COUNTY

The type of agriculture practiced most extensively in the county at the present time is livestock farming or a combination of livestock farming and grain farming, commonly known as the general farming system. The major portion of the grain and forage crops are grown for feed on the farms. The farm income of the county is derived mainly from the sale of hogs, beef cattle and dairy products. Dairying is an important industry and is carried on to some extent on most farms. Many farmers sell considerable amounts of milk to the local creameries but in general dairying is practiced in conjunction with other livestock operations and is subordinate to them.

On most farms the raising and fattening of hogs is the chief industry. The feeding of beef cattle is also an important industry and sheep raising is practiced to a small extent.

Corn is the most important crop grown and practically all of it is fed on the farms. There is about as large an acreage of oats as of corn. The acreage in hay exceeds that devoted to the grain crops and practically all of the hay produced is utilized for feed. Some vegetables are grown for market, particularly near Dubuque, but not on a very large scale commercially. Orcharding is practiced in a small way but is not an important industry.

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*Soil Survey of Dubuque county, Iowa, by J. O. Veatch of the U. S. Dept. of Agr. and C. L. Orrben of the Iowa Agr. Expt. Station.

TABLE I. AVERAGE YIELDS AND VALUE OF CROPS GROWN IN DUBUQUE COUNTY, IOWA*

Crop	Acreage	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	66,000	18.22	47.0	3,102,000	$0.54	$1,675,480
Oats	53,000	14.63	41.0	2,173,000	0.34	738,820
Winter wheat	550	0.15	20.0	11,000	0.97	10,670
Spring wheat	870	0.24	20.0	17,400	0.95	16,530
Barley	850	0.23	28.0	23,800	0.52	12,376
Rye	250	0.06	20.0	5,000	0.71	3,550
Potatoes	2,010	0.55	126.0	253,260	0.62	157,121
Tame hay	67,300	18.58	1.6	107,680	10.40	1,119,872
Wild hay	480	0.13	1.3	624	8.50	5,304
Alfalfa	70	0.01	3.3	231	14.80	3,418
Pasture	150,000	41.41	....	.....	.....	.....

*Iowa Yearbook of Agriculture 1922.

There is a considerable acreage in waste land in the county, some of which might be reclaimed and made productive thru proper methods of soil treatment. Considerable areas used for pasture are of less value than they should be and might readily be made highly satisfactory pastures. In many cases the land is suitable only for pasture purposes. There are other areas, however, where special treatments might make the land suitable for general or special crops. General recommendations regarding the reclamation of waste land cannot be given as the causes of infertility are too variable. In a later section of this report suggestions will be offered as to the best methods for handling certain individual soils and the reclamation of waste areas of the various soil types will be considered. In cases where the conditions are abnormal, suggestions regarding methods of treatment may be secured by corresponding with the Soils Section of the Agricultural Experiment Station.

DUBUQUE COUNTY'S CROPS

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

Corn is the most important crop in value and it occupies only a slightly smaller acreage than hay. It is grown on more than 18 percent of the total farm land of the county and in 1922 average yields of 47 bushels per acre were secured. On the more productive soils, with the best seasonal conditions, yields of 60 to 70 bushels per acre are frequent. The dark colored upland soils and certain of the bottom land types in favorable seasons yield the best, while the lowest yields are secured on the more sandy soils especially in the seasons of low rainfall. The most common variety grown is Reid's Yellow Dent or strains of this variety. The crop is mainly utilized on the farms as feed for the hogs, beef cattle and dairy cattle. Much of it is used for silage. In 1922 there were 238 silos in the county, and 19,203 tons of silage were put

up. That portion of the crop which is not utilized on the farm is disposed of on outside markets.

Hay is grown on the largest acreage in the county, tame hay being the most important and occupying 18.58 percent of the total farm land. Wild hay is grown only on a small area and is relatively unimportant. The principal hay crop is a mixture of timothy and red clover and average yields amount to 1.6 tons per acre. Some timothy is grown alone and occasionally clover is grown separately, usually for seed. The major portion of the hay produced is utilized on the farms as winter feed for beef and dairy cattle and the work stock. The surplus is disposed of locally.

The third crop in value in the county is oats. This crop occupies 14.63 percent of the total farm land and average yields for 1922 amounted to 41 bushels per acre. The varieties most generally grown are Iowa 103, Swedish Select and Silver Mine. Most of the oats grown are fed on the farms.

Potatoes are grown on most farms and the total acreage in this crop is large. Average yields of 126 bushels per acre are reported. The value of the crop is considerable.

Wheat was formerly the most important crop in the county, but during recent years the acreage has decreased until at present only a relatively small area is utilized for this crop. A slight increase in acreage during the war has been followed by a decrease since. Both winter wheat and spring wheat are grown, the latter occupying the greater acreage. The average yields of both crops are 20 bushels per acre. The crop is of minor importance.

Barley is grown to some extent and average yields of 28 bushels per acre are secured. Formerly it was an important cash crop but at the present time practically all of the barley grown is utilized on the farms as feed for hogs and cattle. Some rye is grown, but it is relatively an unimportant crop.

Alfalfa is produced on a few areas and average yields of 3.3 tons per acre are reported. With greater care in seeding and preparation of the soil, highly profitable yields might be secured. The growing of alfalfa should certainly be encouraged in the county.

Other crops of minor importance in the county are rape, sorghum, millet, popcorn and soy beans. Vegetables, melons, grapes, strawberries and certain bush fruits are grown on many farms and utilized for home consumption. On a few small farms these crops are the principal ones grown. Areas of more sandy soil along the Mississippi river near the city of Dubuque are well suited for the growth of vegetables, and many of the steep hillsides might be utilized profitably for the growing of bush fruits and grapes. Practically all of these products are sold locally.

Orcharding is practiced only on a small scale, the fruits grown consisting mainly of apples, cherries and plums. The product is usually sufficient for home needs and to supply local markets.

DUBUQUE COUNTY'S LIVESTOCK BUSINESS

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

The following figures from the Iowa Yearbook of Agriculture for 1922 indicate the extent of the livestock industry in the county.

Horses, all ages	10,581
Mules, all ages	253
Swine, on farms July 1, 1922	122,305
Swine, on farms January 1, 1923	63,671
Cattle, cows and heifers kept for milk	21,269
Cattle, other cattle not kept for milk	27,122
Cattle, total, all ages, January 1, 1923	48,391
Sheep, all ages, on farms January 1, 1923	3,773
Sheep, shipped in for feeding, 1922	388
Sheep, total pounds of wool clipped	31,761
Poultry, total number of varieties	278,060
Poultry, number of dozen eggs received 1922	1,079,729

On the majority of farms the principal industry is the raising and fattening of hogs and the major portion of the farm income is derived from the sale of hogs. The breeds commonly grown are grades of Duroc Jersey and Poland China.

Dairying is an important industry and is carried on to some extent on most of the farms, chiefly, however, as a part of the general farming system. Creameries are located in Dubuque and in most of the smaller towns, and are easily accessible to the farmers for the sale of surplus milk. Considerable areas are suitable chiefly for pasture purposes and support excellent stands of blue grass and hence excellent pasturage is provided for the dairy herds, during the summer and early fall.

The feeding of beef cattle is an important industry and the sale of beef cattle provides a considerable income on many farms.

Sheep raising is practiced to some extent but is relatively an unimportant industry. A few horses are raised on most farms but the industry is not developed to any extent. Poultry is raised on practically all farms and a considerable income is derived from the sale of poultry and poultry products. This industry might be developed to some extent if it received more attention. Poultry and poultry products are chiefly utilized for home consumption, there being only a small sale of these products out of the county.

VALUE AND CONDITION OF DUBUQUE COUNTY LAND

The value of land in Dubuque county is widely variable, depending upon soil conditions, location with reference to towns and railroads, improvements on the farms and topography. At the time of the survey in 1920 the average price of the most desirable farm land was $200 to $250 per acre. In some cases much higher prices had been secured, but these should be considered quite abnormal. The more hilly areas and land more distantly located from the towns and railroads may be obtained at $100 to $150 per acre. Pasture areas of steep, uncultivated upland sell for $30 to $60 per acre.

Average yields of general farm crops grown in Dubuque county at the present time are quite satisfactory. Larger crops might be secured in many cases if better methods of handling the soils were practiced. There are many cases where the soils are injured to a considerable extent by erosion or the carrying away of the fertile surface soil either by sheet erosion or by gullying both of which may occur frequently in the rougher areas. The steep phase of the Clinton silt loam and areas of the typical Clinton and of several others of the upland types on the more rolling areas are apt to be more or

less seriously injured by erosion. In many areas, the land should undoubtedly be kept in pasture and not cultivated. In some cases, however, the adoption of some method for the reclamation of the eroded areas or the prevention of erosion is very necessary. From among the suggestions given later in this report some method may be chosen which will permit of the reclamation or satisfactory handling of many washed or eroded areas. In some cases the land may be improperly drained and when this is true drainage should be practiced as the fundamental treatment. Satisfactory crop growth cannot be secured on land which is too wet, and installation of tile should undoubtedly be practiced in certain cases.

Dubuque county soils are practically all acid in reaction and satisfactory yields of crops, particularly of legumes, will not be secured unless the proper amount of lime is applied to remedy the acid conditions. There is a wide variation in the lime needs among the various soils and general recommendations regarding the application of lime cannot be made. It is important that the particular soil be tested to determine its lime needs and that the lime be applied before a legume is seeded.

Many of the soils in the county are not particularly well supplied with organic matter and in no case is the supply so large that future additions will not be needed. Applications of farm manure have proven of large value on all the soils, giving practically as large effects on the richer, apparently more fertile soils, as on the more unproductive areas. The increases in crop yields secured by the use of manure are always profitable. All crop residues should be utilized to aid in maintaining the organic matter content in the soil. These materials should never be burned or destroyed as they have a definite fertility value.

There are cases in which leguminous crops should certainly be used as green manures in order to increase the content of organic matter and nitrogen in the soil. It is particularly important that green manuring be practiced where the supply of farm manure is not adequate to permit of an application to the entire area of the farm. It is usually more satisfactory to distribute the farm manure produced over the farm and supplement it by turning under a legume crop, or at least a portion of a crop, and in this way the largest beneficial effects on the soils from the fertility standpoint may be secured. On the rougher, more rolling areas the addition of organic matter in the soil is particularly important as it aids in preventing the washing of the surface soil. But on all of the soils great care should be exercised in building up and maintaining the supply of organic matter and nitrogen thru the proper use of farm manure, leguminous green manure and crop residues.

The content of phosphorus in the soils of Dubuque county is not high and in most cases is rather low. It seems evident, therefore, that phosphorus fertilizers will undoubtedly be needed on these soils in the near future, even if they do not prove of value at present. There is some evidence, however, from farm experience and from experiments, that phosphates may be of value at the present time. It is not yet possible to say whether acid phosphate or rock phosphate should be employed, as the results which have been secured with these two materials indicate in many cases a similar value from both.

While on one soil one phosphate may prove desirable, under different soil conditions the other material may seem preferable. It is urged, therefore, that farmers test their own soils by means of simple field experiments and determine whether or not a phosphorus fertilizer might be used profitably and also whether they should apply the acid phosphate or the rock phosphate. Many farmers are actually carrying on tests of this nature and are securing very interesting and very important results.

Complete commercial fertilizers cannot be recommended for use in this county at the present time on general farm crops. Farmers who are interested may test these materials in comparison with acid phosphate and thus determine whether or not their use is at all desirable. For truck crops special brands of complete commercial fertilizers may often be used very profitably and in such cases farmers should secure a particular brand which gives the best results. Again it would be very desirable to test the material before making any extensive applications.

THE GEOLOGY OF DUBUQUE COUNTY

Thruout most of Dubuque county the rock formations underlying the soils have been buried so deeply by the deposits of glacial material and loess that they have little influence upon the character of the soils. Only in the case of the Dubuque silt loam and the Gasconade loam is the soil derived from the underlying rock material. In these two deposits the covering of drift and loess has been largely removed by erosion and the soil has been produced chiefly from the weathering of the limestone. These two soil types which are considered residual soils, occupy about eight percent of the total area of the county.

During the glacial age great masses of ice known as glaciers swept over the county and upon their retreat left behind thick deposits of debris or glacial till. The movement of the glaciers brought about a leveling of the surface features of the county, and retreating, they filled up the old valleys. There is very little evidence of the earlier glaciation in the county but the later glacier, known as the Iowan, laid down a thick layer of till and from it the soils of the county, classified in the Carrington, Shelby, Lindley and Clyde series, have been derived.

The soils derived from this glacial material are extremely variable in texture and they contain considerable amounts of sand and gravel. They are distinguished from the loessial soils on the basis of the content of coarse material and they are divided into series and types on the basis of their color, topography, surface and subsoil characteristics and texture. The darker colored soils with the heavier subsoils are classified in the Carrington series. The lighter colored types with more gravelly subsoils are classified in the Shelby and Lindley series. The soils developed under poor drainage conditions with dark colored surface soil and heavier impervious subsoils are classified in the Clyde series.

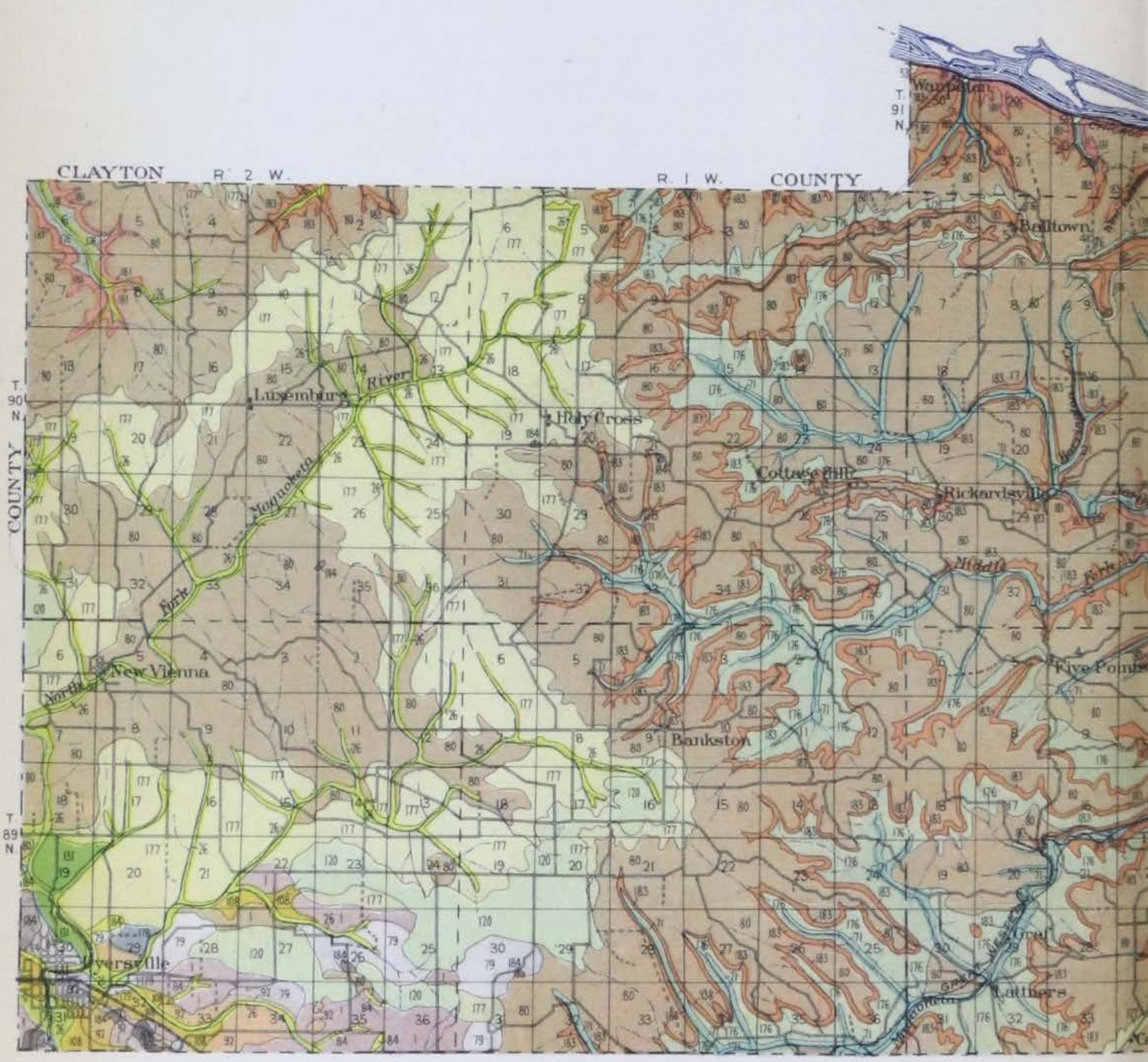
The drift deposit in the county is quite variable in thickness and it may extend to a depth of 100 feet. Ordinarily it is not over 30 or 40 feet in

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

SOIL MAP OF DUBUQUE COUNTY

Thomas D. Rice, Inspector, Northern Division.
Soils Surveyed by J. O. Veatch of the U. S. Depa
ment of Agriculture and C. L. Orrben of the Iowa
Agricultural Experiment Station.

NORTH HALF



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

LEGEND

Drift Soils

1 — Carrington loam

92 — Shelby fine sandy loam

79 — Shelby loam

84 — Clyde silt loam

185 — Lindley fine sand

Loess Soils

80 — Clinton silt loam

176 — Clinton silt loam (steep phase)

120 — Tama silt loam

177 — Tama silt loam (light colored phase)

178 — Clinton very fine sandy loam

Terrace Soils

179 — Judson loamy sand

108 — O'Neill loam

131 — Judson silt loam

180 — Davenport clay loam

Swamp and Bottomland Soils

71 — Genesee silt loam

76 — Wabash silt loam

181 — Wabash stony silt loam Colluvial phase

182 — Genesee silty clay loam

53 — Riverwash

117 — Genesee fine sandy loam

Residual Soils

183 — Dubuque silt loam

184 — Gasconade loam

SCALE: 1 INCH 2½ MILES

AMERICAN LITHO.& PTG.CO. DES MOINES

thickness. The earlier Kansan glaciation was probably much thinner but there is little evidence of this deposit at the present time.

At some geological time following the glacial age, when conditions were very different than at present, there was deposited on the surface of a considerable portion of the county, a layer of fine silt-like material which is known as loess. In thickness this loessial deposit ranges from 10 to 30 feet or more. It is composed naturally of a grayish and yellow silt. As the material has weathered, however, the color has changed from a buff color to yellowish-brown and the original high content of lime has been washed away in the drainage water. The surface soils have been further modified by the growth of vegetation and the accumulation of organic matter. On those soils which have been formed under wooded conditions the soils of the Clinton series have been developed. These are characterized by a yellowish to buff colored surface soil with a subsoil consisting of a silty clay loam.

The Tama series has been developed on the prairies under less rolling topographic conditions and there has been a larger accumulation of organic matter; consequently this soil is darker in color and ordinarily somewhat more fertile. The disappearance of lime has, however, been rather complete in the case of both series.

The terrace and bottomland soils in the county have been formed by the earlier streams which brought about the drainage of the land and by the more recent alluvial deposits of the present drainage system. The terrace soils are somewhat variable in characteristics as would be expected and many of them lie 30 to 50 feet above the present flood plains.

The O'Neill soils are characterized by loose sand and gravel in the subsoil. While they are quite uniformly dark colored at the suface they are apt to be droughty. The Judson soils are uniform in texture and structure, frequently to a depth of three feet or more. The Davenport soils have heavy clay subsoils and usually contain lime in the subsoil.

The soils on the first bottoms are classified in the Wabash and Genesee series, and are distinguished on the basis of their color. They are extremely variable in composition and characteristics and are subject to frequent overflow and hence change in appearance and character. The Genesee soils have a lighter colored surface soil while the Wabash soils are dark colored in the surface and somewhat darker in the lower soil layers. These bottomland types are derived chiefly from the loessial material washed down from the upland or from the drift deposits on the upland, and hence they are composed of a mixture of material of loessial and glacial origin.

PHYSIOGRAPHY AND DRAINAGE

The topography of Dubuque county is quite variable in the different parts of the county. In the western portion the land is somewhat less hilly and rolling than that in the eastern part, but there are no areas where the surface is level or flat, except narrow strips along the streams. In the extreme northwestern part and also along some of the larger streams in the southwestern part, bluffs and hills are found, but the roughest section of the county is found in the eastern part along the Mississippi river. The river flows

thru a valley or gorge, walled in by rocky bluffs which often reach a height of 300 feet. The tributaries to the river flow thru comparatively narrow valleys 200 to 400 feet in depth and where they join the main stream they are bordered by strips of rocky bluffs.

At distances varying from one to ten miles west of the Mississippi river there is generally an abrupt change in elevation of the land sometimes as much as a 200 to 300 foot difference within a distance of one-half to one mile. This change in topography is quite striking and the slopes toward the east are more steep and bluff-like and underlaid with limestone, while to the west the lower slopes underlaid with soft shale are somewhat rounded and more gently sloping.

The drainage of Dubuque county flows to the Mississippi river, all of the streams from the eastern part flowing directly toward the river while in the western part of the county in the more gently rolling areas the streams flow southward or even westward but ultimately reach the Mississippi. The main streams have formed deep courses and have developed numerous tributaries. The drainage of the county as a whole is therefore quite complete.

The chief streams draining the eastern part of the county are the Middle Fork Maquoketa river, Little Maquoketa river, North Fork Maquoketa river, Catfish creek, North Fork Catfish creek, Middle Fork Catfish creek and Gonger creek. The western part of the county is drained mainly by the

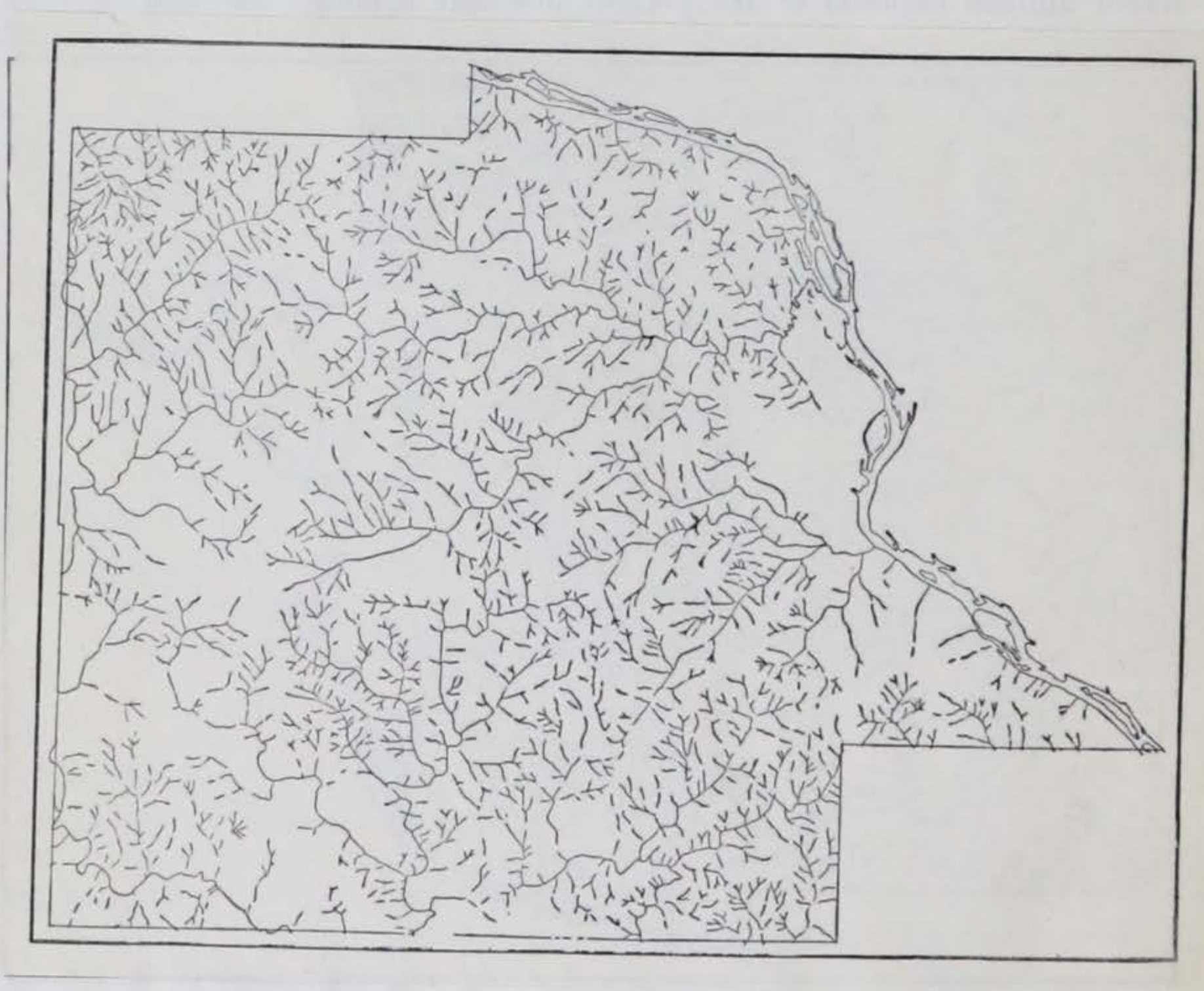


Fig. 3. Map of natural drainage system of Dubuque county.

North Fork Maquoketa river, with its tributaries. The same river, John creek, White Water creek, Curran Branch, Prairie creek, Little creek and Buncomb creek drain the southern part of the county. All of these streams possess numerous tributaries which extend into all parts of the upland, cutting the land considerably but providing a very thoro drainage system.

The accompanying drainage map indicates the rather complete drainage system of the county. There are some instances where the installation of tile would probably be of value as there are cases where the subsoil conditions permit of the retention of too much moisture for the best crop growth. The soils of the Clyde series for example, and of the Davenport series on the terraces, certain areas in the Carrington loam and in some other types would be benefited by a more complete tiling.

Drainage is not an important factor in this county but in individual local areas the installation of tile might often be practiced to advantage and wherever the soil is too wet, it is very desirable that precautions be taken to bring about the more thoro removal of excess water.

THE SOILS OF DUBUQUE COUNTY

The soils of Dubuque county may be divided into five groups according to their origin and location. These groups include drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils.

Drift soils are formed from the material carried by glaciers or ice sheets and left behind on the surface of the land when the glacier retreated. They are extremely variable in composition and are filled with pebbles and boulders.

Loess soils are fine dust-like deposits made by the wind at some time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them or by a deepening of the river channel.

Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams and subject to more or less frequent overflow. Residual soils are derived from the weathering of the underlying rock materials and remaining in place above the rock from which they were formed.

The extent and occurrence of these groups of soils in Dubuque county are shown in table II. Almost three-fourths of the county, 71.4 percent is covered by the loessial upland types. The drift soils are minor in extent, covering only 9.6 percent of the county. The terrace soils are all small in area and

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

Soil Group	Acres	Percent of total area of county
Drift soils	36,800	9.6
Loess soils	274,560	71.4
Terrace soils	4,992	1.2
Swamp and bottomland soils	37,888	9.9
Residual soils	30,400	7.9
Total	384,640	....

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN DUBUQUE COUNTY

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
1	Carrington loam	17,536	4.6
92	Shelby fine sandy loam	9,792	2.5
79	Shelby loam	7,808	2.0
84	Clyde silt loam	1,024	0.3
135	Lindley fine sand	640	0.2
	LOESS SOILS		
80	Clinton silt loam	173,632	
176	Clinton silt loam (steep phase)	20,224	50.4
120	Tama silt loam	30,336	
177	Tama silt loam (light colored phase)	45,056	19.6
178	Clinton very fine sandy loam	5,312	1.4
	TERRACE SOILS		
179	Judson loamy sand	2,112	0.5
108	O'Neill loam	1,664	0.4
131	Judson silt loam	960	0.2
180	Davenport clay loam	256	0.1
	SWAMP AND BOTTOMLAND SOILS		
71	Genesee silt loam	16,064	4.2
26	Wabash silt loam	8,192	2.1
181	Wabash stony silt loam (colluvial phase)	6,208	1.6
182	Genesee silty clay loam	4,480	1.2
53	Riverwash	1,536	0.4
117	Genesee fine sandy loam	1,408	0.4
	RESIDUAL SOILS		
183	Dubuque silt loam	29,056	7.6
184	Gasconade loam	1,344	0.3
	Total	384,640	....

the total acreage is small, amounting to only 1.2 percent of the county. The swamp and bottomland soils are about the same in extent as the drift soils, and they cover 9.9 percent of the county. Residual soils are smaller in area, occupying 7.9 percent of the county.

There are 18 individual soil types in the county and these with the steep phase of the Clinton silt loam, the light colored phase of the Tama silt loam, the colluvial phase of the Wabash stony silt loam and the area of riverwash, make a total of 22 separate soil areas. There are 5 drift soils, 5 areas of loess soils, 4 terrace types, 6 areas of swamp and bottomland and 2 residual soils.

The areas of the different soil types in the county are given in table III. The Clinton silt loam is the most extensive soil type and the largest loess area. Together with the steep phase, which is much smaller in extent, it covers 50.4 percent of the total area of the county. The Tama silt loam, light colored phase, is the second largest soil area in the county, being somewhat more extensive than the typical Tama. Together the typical soil and the light colored phase cover 19.6 percent of the total area. The Clinton silt loam and the Tama silt loam, together, cover 70 percent of the county. The remain-

ing soil types are all minor in area and cover comparatively small acreages. The Dubuque silt loam, a residual soil, is the third largest soil area in the county, covering 7.6 percent of the total area. The Carrington loam is the largest drift soil and the fourth largest soil type in the county. It covers 4.6 percent of the total area. The Genesee silt loam is the most extensive bottomland type and the fifth largest type in the county. It covers 4.2 percent of the county. The Shelby fine sandy loam and the Shelby loam are minor drift soils, covering 2.5 and 2.0 percent of the total area, respectively. The Wabash silt loam, stony silt loam (colluvial phase), and the Genesee silty clay loam, are minor bottomland soils, covering 2.1, 1.6, and 1.2 percent of the county respectively. The Clinton very fine sandy loam is a minor loess type covering 1.4 percent of the county. All the terrace types and the remaining drift soils, swamp and bottomland soils and residual types, are small in area, covering less than one percent of the county.

Some relations are evidenced between the individual soil types and the topographic features of the county. Thus the Clinton silt loam is quite generally rolling in topography, varying to rough or steep where it is mapped as the steep phase. The Tama silt loam is found on the more gently rolling upland. The Carrington loam likewise occurs on the rather gently rolling uplands, having, however, a more pronounced topography than the Tama soils. The Shelby and Lindley soils are rolling to rough in topography while the Clyde silt loam occupies depressed areas in the upland. The Dubuque silt loam and the Gasconade loam are found on ridges, slopes, knolls and bluffs, and are very striking in topography. The terraces and bottomland soils are quite generally level in topography and have very indistinct topographic features.

THE FERTILITY IN DUBUQUE COUNTY SOILS

Samples were taken for analyses from the most important soil types in the county. The steep phase of the Clinton silt loam, the areas of O'Neill loam and Judson silt loam, and riverwash were not sampled, owing to their small extent and relative unimportance and in the case of the steep phase Clinton silt loam and the riverwash, the variable nature of the soil material. The more extensive types were sampled in triplicate and one sample was taken from each of the minor soils. All the samples were drawn with care so that they should be entirely representative of the particular types and that all variations which may have been brought about by local conditions or previous treatments should be eliminated.

Samples were taken at three depths, from 0 to 6⅔", 6⅔" to 20", and 20" to 40", representing the surface soil, the subsurface soil and the subsoil respectively. The samples were analyzed for total phosphorus, total nitrogen, total organic carbon, inorganic carbon, and limestone requirement. The official methods were employed in the analyses for phosphorus, nitrogen and carbon, while the Truog test was used in the determination of the limestone requirement.

The figures in the tables are the averages of duplicate determinations on all samples of each soil type and they represent, therefore, the results from four or twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV, being calculated on the basis of 2,000,000 pounds of surface soil per acre. There is wide variation in the phosphorus present in the various soil types of the county, the amount ranging from 1,710 pounds in the Genesee silt loam, down to 727 pounds in the Carrington loam.

There is little relationship evidenced between the various soil groups and the content of phosphorus, altho the bottomland soils average higher in this constituent than the other soil groups. The loess soils will average somewhat higher than the drift types but the difference is not very distinct. The terrace soils seem to be somewhat higher in phosphorus than the upland soils. They are not so well supplied however as the bottomland types. The larger content of phosphorus in the bottomland soils might be expected because of the smaller amount of crop growth from these soils and hence the smaller amount of phosphorus removed.

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

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	727	2,440	28,637	0	6,500
92	Shelby fine sandy loam	1,212	1,360	14,196	0	4,000
79	Shelby loam	1,144	2,640	29,320	0	4,000
84	Clyde silt loam	1,320	6,920	72,891	0	4,000
135	Lindley fine sand	808	440	5,187	0	3,000
	LOESS SOILS					
80	Clinton silt loam	1,073	2,520	26,148	0	4,666
120	Tama silt loam	956	4,060	48,507	0	5,500
177	Tama silt loam (light colored phase)	1,185	1,120	43,680	0	4,000
178	Clinton very fine sandy loam	942	1,560	18,564	0	5,000
	TERRACE SOILS					
179	Judson loamy sand	1,305	1,200	11,029	0	4,000
180	Davenport clay loam	1,508	4,360	47,611	0	3,000
	SWAMP AND BOTTOMLAND SOILS					
71	Genesee silt loam	1,710	2,840	37,018	0	3,000
26	Wabash silt loam	1,131	2,400	23,974	0	4,000
181	Wabash stony silt loam (colluvial phase)	1,347	4,440	53,212	0	3,000
182	Genesee silty clay loam	1,589	2,840	30,937	0	4,000
117	Genesee fine sandy loam	1,373	3,840	38,220	0	5,000
	RESIDUAL SOILS					
183	Dubuque silt loam	1,050	2,600	33,306	0	3,000
184	Gasconade loam	754	2,760	40,950	0	2,000

The relationships among the individual soil types with respect to their phosphorus content, is much more distinct. The Clyde silt loam is richer in phosphorus than the other drift soils. The Lindley and Carrington soils are lower than the Shelby types. Ordinarily the Carrington soils are richer than the Shelby types. The particular sample of Carrington loam analyzed in this work was evidently low in plant food constituents. The Tama soils are ordinarily a little better supplied than the Clinton but the differences in the soils in this county are too small to be distinctive. The Davenport clay loam on the terraces is richer than the Judson loamy sand in the same position. In the bottoms the Genesee types seem to be richer than the Wabash soils. Again, this is contrary to the usual relation between these series, but the differences are not extremely large. The Dubuque silt loam is higher than the Gasconade loam, as might be expected from the fact that it is a deeper soil.

There is apparently some relationship between the content of phosphorus and the texture of the soil, altho there is not opportunity to make many comparisons as there are not many types of the various series represented in the county. The Clinton silt loam is richer than the Clinton very fine sandy loam. The Genesee silty clay loam is higher than the fine sandy loam but not any better supplied than the silt loam, altho ordinarily this would be true. The Shelby loam is not quite so high in phosphorus as the Shelby fine sandy loam. The difference however, is very small. Ordinarily a loam will run somewhat higher than a fine sandy loam.

All the comparisons which are possible among the various soil types in the county, reflect in a general way not only the effect of the texture of the soil, but the influence of such characteristics as color, topography or subsoil conditions, which serve to distinguish the various soil series. The Tama soils are not so rolling to rough as the Clinton types. They are darker in color and generally somewhat more productive. The Clyde soils occur in level to depressed areas in the uplands and hence they are richer than the more rolling areas of the Carrington, Shelby, and Lindley. Ordinarily the Carrington soils will appear more fertile than the Shelby and Lindley types, but in this particular case the Carrington loam sample was lower in phosphorus than the samples of the other types. It is usually darker in color and less rolling in topography and hence higher in plant food. The differences between the soils in the terrace groups are undoubtedly due mainly to the textural differences. In the swamp and bottomland group the Genesee and Wabash soils are distinguished on the basis of color. There may be some relation here between phosphorus content and the color of the soils. It is generally true that finer textured soils, dark in color and more nearly level in topography, are better supplied with phosphorus than coarse textured soils, light in color and more rolling in topography. These relations are borne out to a certain extent by the results secured on the soils of Dubuque county.

Considering the analyses of the soils of the county as a whole, it seems quite evident that there is no large amount of this element present in any of the soils and in many cases, phosphorus may be the limiting factor in crop

growth. Where the total content of phosphorus is as low as it is in many of the soils of this county, it is almost certain that there will be an insufficient production of the element in an available form. Even where the supply of this element is high, there is no assurance that there will be a sufficient production of available phosphorus to keep crops supplied. Phosphorus fertilizers will undoubtedly prove of value on many of the soils of this county at the present time, to judge from the analyses alone. The experimental results obtained in the greenhouse and in the field experiments on the same soil types in other counties, confirm this conclusion.

Acid phosphate or rock phosphate may be applied to the soils in this county with profit, the former material giving more immediate effects. It cannot be said, however, which phosphate should be used in order to give the most profitable returns when the crop effects are considered over a period of at least one rotation. The experiments which are being carried on thruout the state comparing these two phosphates do not yet permit of definite conclusions, but will later show which fertilizer should be employed on any individual soil type. At the present time it is only possible to recommend to the farmers of Dubuque county that they determine the value of phosphorus fertilizers on their own soils, testing the relative effect of both the acid phosphate and the rock phosphate on small areas and thus determine whether or not their soils will respond profitably to phosphates and which material should be employed.

The nitrogen content of the soils of the county is likewise extremely variable ranging from 6,920 pounds in the Clyde silt loam down to 420 pounds in the Lindley fine sand. As was noted in the case of phosphorus, there is some relation between nitrogen supply in the soils and the groups of soils. The bottomland types are richer than the upland types on the average. The variations between the loess and drift soils, however, are not distinct. The same is true of the residual soils and terrace types. It would be expected that the bottomland soils would be richer in this constituent owing to the lack of plant growth and the removal of plant food by crops grown.

There is some relation between the nitrogen content and the soil series. Thus the Clyde soils are higher than the Shelby, Carrington or Lindley types. The Tama silt loam is higher than the Clinton silt loam. The Davenport soils are higher than the Judson types on the terraces. These relationships reflect the color of the soil and the topographic position to a very large extent. Lighter colored soils like the Shelby and Lindley will run lower in nitrogen than the dark colored soils like the Clyde and Carrington. Level to flat soils like the Clyde are always higher in nitrogen than the more rolling types. The Tama silt loam is darker than the Clinton and more gently rolling in topography, and hence higher in nitrogen.

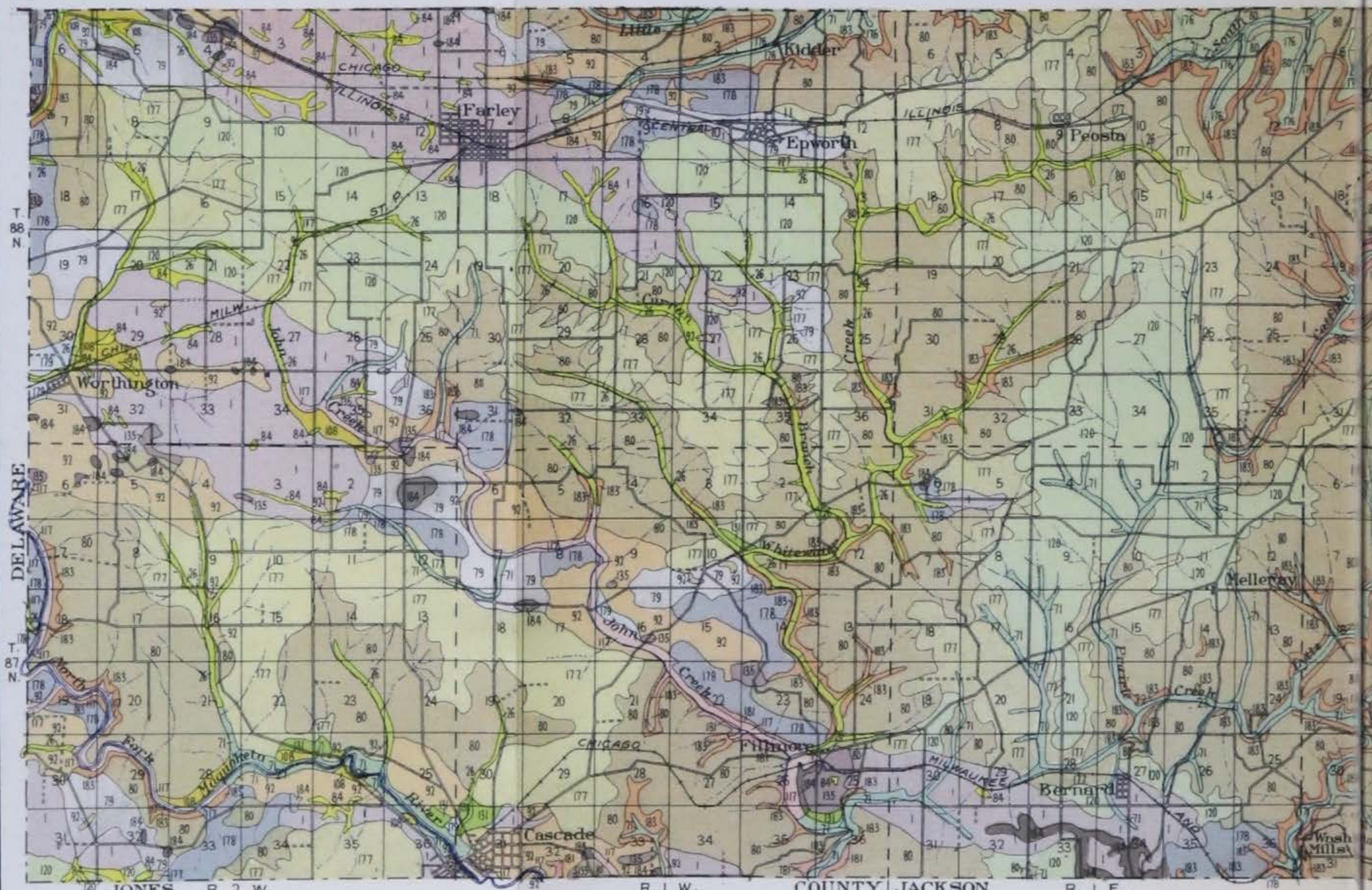
There are relations also between soil texture and the nitrogen content, altho there are not a large number of soils of different textures in the same soil series, in the county. The Shelby loam is richer than the Shelby fine sandy loam. The Tama silt loam is much higher than the light colored phase. The Clinton silt loam is richer in nitrogen than the very fine sandy loam. Comparisons among the bottomland types are not possible as the differences

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

SOIL MAP OF DUBUQUE COUNTY

Thomas D. Rice, Inspector, Northern Division
Soils Surveyed by J. O. Veatch of the U. S. Department of Agriculture and C. L. Orrben of the Iowa Agricultural Experiment Station.

SOUTH HALF



Residual Soils

183 — Dubuque silt loam

184 — Gasconade loam

Swamp and Bottomland Soils

71 — Genesee silt loam

26 — Wabash silt loam

181 — Wabash stony silt loam Colluvial phase

182 — Genesee silty clay loam

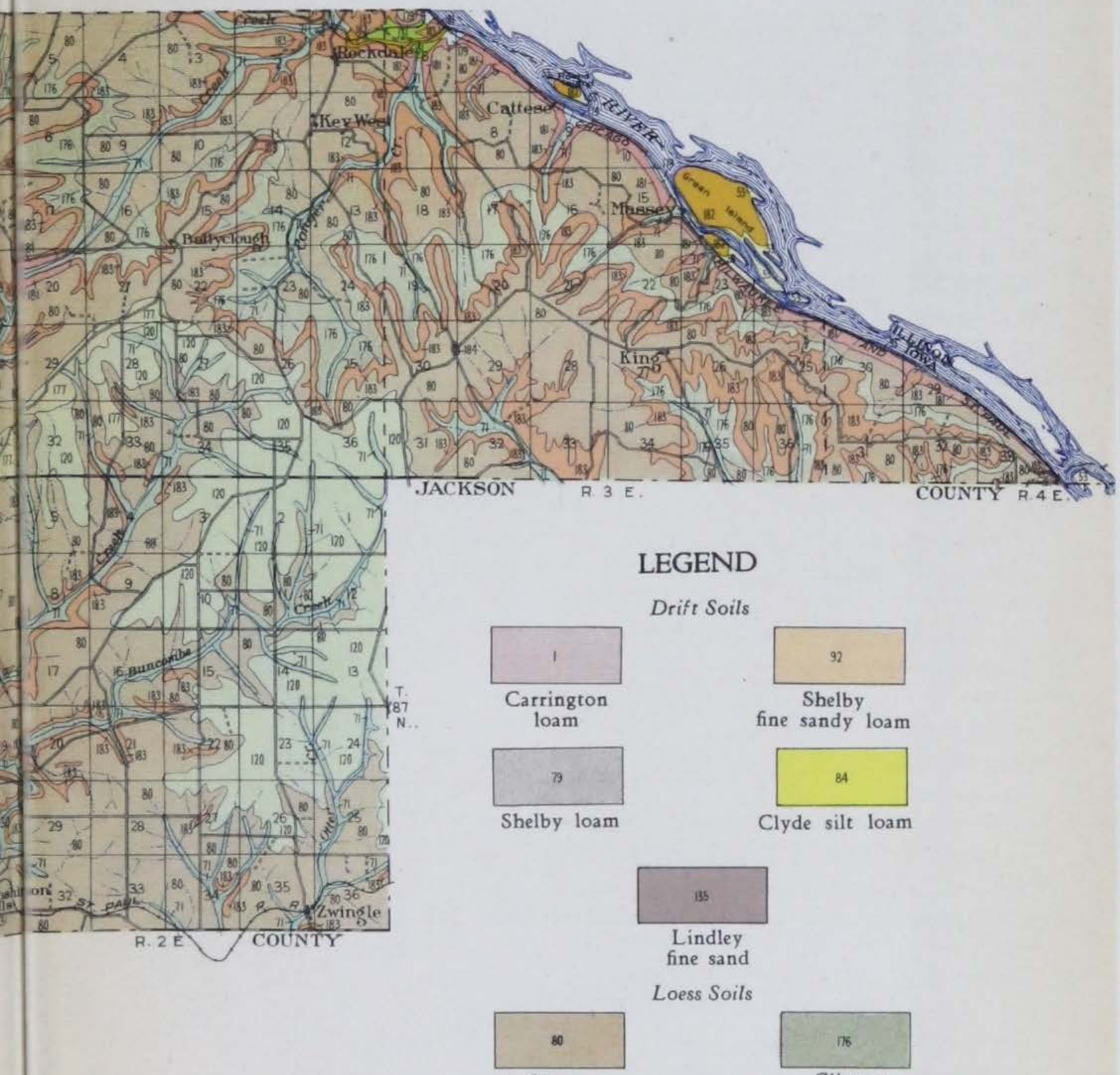
53 — Riverwash

117 — Genesee fine sandy loam

SCALE: 1 INCH 2½ MILES

AMERICAN LITHO. & PTG. CO. DES MOINES

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



LEGEND

Drift Soils

1 — Carrington loam

92 — Shelby fine sandy loam

79 — Shelby loam

84 — Clyde silt loam

135 — Lindley fine sand

Loess Soils

80 — Clinton silt loam

176 — Clinton silt loam (steep phase)

120 — Tama silt loam

177 — Tama silt loam (light colored phase)

178 — Clinton very fine sandy loam

Terrace Soils

108 — O'Neill loam

180 — Davenport clay loam

are not sufficiently great. In general the fine textured types, dark in color and more level to flat in topography, are higher in nitrogen than coarse textured soils lighter in color and rougher in topography. Ordinarily the color, texture and topography of a soil will indicate the nitrogen content.

With one or two exceptions the soils of Dubuque county are not strikingly deficient in nitrogen but in several cases the amount present is not adequate for any long continued production of large crops and in practically all cases the nitrogen content is such that this element must be considered in planning systems of fertility. Nitrogen is constantly removed from soils by crops and large amounts are washed away in the drainage water. It may disappear from soils in other ways. If the content of nitrogen is to be kept up and soils are to continue to be productive, nitrogen must be returned at regular intervals.

Farm manure is the most common fertilizer employed on the farm and it is very important as a source of nitrogen. When properly cared for and applied, it returns to the land much of the nitrogen removed from the soils by the crops grown. Hence it materially reduces the losses of nitrogen from the soil thru cropping. The application of farm manure ordinarily brings about considerable increases in crop yields. These are undoubtedly due in part at least to the nitrogen supply. The soils of Dubuque county may be benefited materially thru the use of farm manure which will aid in maintaining the supply of nitrogen.

Large applications of manure are not possible on all soils on the farm and hence it is not possible to increase the nitrogen content to any large extent by the use of manure alone. On light colored, light textured poorer soils, some other means must be employed to increase the nitrogen supply, but on the richer soils farm manure is a very important fertilizer for keeping up the nitrogen content.

Green manuring with legumes is an important operation on farms where manure is not available in sufficient quantities to be applied to all the soils, and also on many farms as a supplement to the use of farm manure. On soils poor in nitrogen, the growing of well inoculated legumes and the turning under of these crops in the soil, is very desirable, in order to build up the soils in nitrogen. When well inoculated as the legumes should be, they take much of their nitrogen from the atmosphere, and when the entire crop is turned under as a green manure there is a large increase in the nitrogen content of the soil. If the legume crop is removed from the land, it will have little value as a nitrogenous fertilizer. If only a portion of the crop is turned under, its value will depend upon the amount of material actually incorporated with the soil. When the seed only of the legume is removed, there is a considerable addition of nitrogen to the soil. Thus the method of handling the legume crop will determine the extent to which it will serve as a nitrogenous fertilizer.

The thoro utilization of all crop residues aids materially in maintaining the nitrogen content and these materials should never be destroyed. If the nitrogen content is to be kept up, crop residues and farm manure should be thoroly utilized and at least a part of the legume crops plowed under as green

manures. On some of the soils, particularly the light colored sandy types, green manuring should be practiced more extensively.

There is usually a rather distinct relationship between the nitrogen in soils and the organic carbon content. The latter constituent indicates the content of organic matter. The color of the soil also indicates the amount of organic matter present. Black soils are high in organic matter and hence in organic carbon, while the light colored soils are low in these constituents. The color of the soil also indicates the nitrogen supply. Dark colored types are generally high in nitrogen while light colored soils are apt to be low or even deficient in this constituent. The color of the soil may therefore be taken to indicate quite accurately the need of nitrogen and organic matter and hence the desirability of supplying fertilizing materials containing these constituents.

There is a wide variation in the color of the soils of Dubuque county and hence a similar variation in the content of organic carbon. The differences in content of different constituents among the various soil types are very similar to the variations in nitrogen content which have already been discussed.

The amount of organic carbon ranges from 5,187 pounds in the Lindley fine sand up to 72,891 pounds in the Clyde silt loam. These are the same types which show the lowest and highest amounts of nitrogen. The relations among the various types are very similar in the case of the organic carbon to those noted with nitrogen. The Tama soils are higher than the Clinton, the Clyde are higher than the Carrington, Lindley or Shelby. The Davenport soils are better supplied than the Judson. Texture relations are also evidenced. The Shelby loam is higher in organic carbon than the fine sandy loam. The Clinton silt loam is better supplied than the fine sandy loam. Comparisons among the bottomland types are not possible owing to the variations in these soils and to the minor differences noted in the analyses.

There is evidence of a direct relationship between color, topography, and soil texture and the carbon content, however. Dark colored soils level in topography and heavy in texture, are higher in carbon than light colored rolling soils, coarser in texture. Heavy textured types such as silty clay loams are better supplied than sandy soils. There are some variations among soil types which do not follow this general relationship, but usually the color of the soil bears a distinct relation to texture, topography, organic carbon and nitrogen supply.

The relative amounts of organic carbon and nitrogen in soils indicate the character of the decomposition processes going on in the soils and from this relation it may be determined how rapidly plant food in an available form is being supplied to the crops. If the relationship between these constituents is not the best, there will be a low production of available food and crops will not grow properly.

In most cases the relation in the soils of Dubuque county is fairly satisfactory. In several instances, however, it is not at the best and the production of available plant food is a little slow for the best crop growth. Thus in the Shelby fine sandy loam, the Clyde silt loam, the Clinton silt loam, the Judson loamy sand, the Wabash silt loam, the Genesee silty clay loam and fine sandy loam, the fertility of the soils would be improved considerably by

a stimulation in the decomposition processes so that there might be a larger production of available plant food. This stimulation may be brought about most satisfactorily by the use of farm manure. It is the most valuable fertilizing material from this standpoint, as it supplies bacteria and easily decomposable organic matter and greater amounts of plant food are changed into a utilizable form. On the soil types mentioned, applications of farm manure would be of particularly large value and the desirable effects brought about would be due undoubtedly in large part to the stimulation of bacterial action. Some of the types are low in organic matter and light in color and should be built up in organic matter.

Farm manure should be used on all the soils in the county as far as it is available for use. The ordinary application of 8 to 10 tons per acre will probably be adequate on the better soils, but on the poorer types larger amounts might be profitably employed. On most farms, however, the production of farm manure will not permit of larger applications and hence green manuring is a desirable practice.

On grain farms the use of legumes as green manures is particularly essential to build up the organic matter content. Crop residues should also be thoroly utilized. A careful return of these materials and the proper preservation and application of farm manure and the turning under of leguminous crops as green manures will make it possible to increase and maintain the organic matter content of Dubuque county soils and these materials will also aid in maintaining and increasing the nitrogen supply. The use of farm manure will have an additional value on many of the soils because of the stimulation in available plant food production.

None of the soils of Dubuque county contain any inorganic carbon and hence they are all in need of lime. The lime requirements as shown in the tables, are considerable. With two exceptions the lower soil layers are also acid in reaction and hence there is particular need for the use of lime. If the best growth of crops, particularly of legumes is to be secured, all the soils of the county should be tested for lime requirement and the amount indicated as necessary, should be added.

The figures given in the table for lime requirement merely indicate the needs of the particular soil types and they should not be considered to show the exact amount of lime needed by any particular soil. There is a wide variation in the lime requirements of soils and even samples of the same type will differ widely in many cases. It is important to apply the right amount of lime and to do this the soil from each field on the farm should be tested separately. Farmers in Dubuque county may test their own soils or have them tested, and they should then apply the lime required if most desirable results are to be secured.

Further tests of the soil are necessary at regular intervals, at least once in a rotation, preferably preceding the legume crop, in order that the supply of lime may be maintained in the soil. Farmers who have applied lime to acid soils, have secured large crop increases and the practice has been found to be distinctly profitable. It can, therefore, be recommended.

THE SUBSURFACE SOILS AND THE SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil. The lower soil layers in Dubuque county do not seem to be unusually high in any of the essential plant food constituents and hence it will not be necessary to discuss the analytical data in detail. There is little effect on the fertility of the soil from the supply of constituents in the lower soil layers unless there is a very large content of some one of the plant food elements. The results secured from the analyses of the lower soil layers may be considered, therefore, merely to support the conclusions drawn in the discussion of the analyses of the surface soil.

It is evident that phosphorus fertilizers will be needed in the near future and indeed it seems quite probable that they might be used profitably at the present time. All the evidence available from the analyses and from experimental work indicates that farmers should test the effect of phosphate fertilizers on their soils and determine their value. They may also compare the

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

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	1,413	3,340	40,185	0	5,500
92	Shelby fine sandy loam	2,316	1,440	13,104	0	3,000
79	Shelby loam	1,938	1,680	17,253	0	5,000
84	Clyde silt loam	2,424	5,520	76,330	0	3,000
135	Lindley fine sand	1,346	408	4,914	0	2,000
	LOESS SOILS					
80	Clinton silt loam	2,011	2,280	26,426	0	6,000
120	Tama silt loam	1,817	5,200	58,688	0	7,000
177	Tama silt loam (light colored phase)	2,236	5,760	72,618	0	4,000
178	Clinton very fine sandy loam	1,508	1,920	16,926	0	6,000
	TERRACE SOILS					
179	Judson loamy sand	1,461	1,960	19,273	0	4,500
180	Davenport clay loam	1,858	2,160	15,080	0	2,000
	SWAMP AND BOTTOMLAND SOILS					
71	Genesee silt loam	3,770	2,240	34,179	0	4,000
26	Wabash silt loam	2,370	4,240	48,597	0	5,000
181	Wabash stony silt loam (colluvial phase)	3,798	5,760	73,720	23,904	0
182	Genesee silty clay loam	2,908	5,120	55,857	0	5,000
117	Genesee fine sandy loam	1,996	3,840	44,226	0	4,000
	RESIDUAL SOILS					
183	Dubuque silt loam	1,616	2,240	29,484	0	4,000
184	Gasconade loam	(not sampled)				

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

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	1,716	1,440	31,613	0	4,500
92	Shelby fine sandy loam	2,667	1,320	13,104	0	3,000
79	Shelby loam	1,926	1,800	13,595	0	5,000
84	Clyde silt loam	2,988	1,800	15,561	0	2,000
135	Lindley fine sand	1,818	360	4,258	0	2,000
	LOESS SOILS					
80	Clinton silt loam	2,653	2,800	20,092	0	7,666
120	Tama silt loam	2,281	3,420	37,008	0	5,500
177	Tama silt loam (light colored phase)	2,787	2,280	16,069	0	4,000
178	Clinton very fine sandy loam	3,111	2,160	12,285	0	5,000
	TERRACE SOILS					
179	Judson loamy sand	2,968	1,560	22,686	0	4,500
180	Davenport clay loam	2,424	2,160	13,923	0	2,160
	SWAMP AND BOTTOMLAND SOILS					
71	Genesee silt loam	4,968	1,920	20,475	0	6,000
26	Wabash silt loam	3,474	2,880	78,184	0	5,000
181	Wabash stony silt loam (colluvial phase	4,808	3,000	37,245	30,732	0
182	Genesee silty clay loam	4,605	6,960	74,445	0	6,000
117	Genesee fine sandy loam	3,231	1,240	17,035	0	4,000
	RESIDUAL SOILS					
183	Dubuque silt loam	4,119	2,280	42,546	27,888	0
184	Gasconade loam	(not sampled)				

value of rock phosphate and acid phosphate and decide which may be used.

The supply of organic matter and nitrogen is not sufficient for all time and in all the soils of the county fertilizing materials which will supply these constituents must be employed regularly. The careful preservation and application of farm manure, the utilization of all crop residues and the turning under of leguminous green manures, will make it possible to keep up the supply of organic matter and nitrogen and will also permit of increasing the amount of these constituents in the soils.

Only two of the soil types show any content of lime in the subsoil and these are the Dubuque silt loam and the Wabash stony silt loam (colluvial phase). All the other soils are acid in the subsoil. The necessity of applying lime to the soils of the county in amounts determined by tests run for that purpose, is emphasized by these analyses. Only by testing soils and applying lime, will the best crop growth be secured. Even on those two types showing lime in the lower layers, the surface soils are acid and the addition of small amounts of lime may be necessary to secure good initial growth of

legumes. Lime rarely moves upward in the soil and hence if the surface soil is acid, lime should be used notwithstanding the presence of lime in the subsoil.

GREENHOUSE EXPERIMENTS

Greenhouse experiments were carried out on soils from Dubuque county in the attempt to determine the value of the application of certain fertilizer treatments. The soils tested were the Clinton silt loam and the light colored phase Tama silt loam, the two most important types in the county. In addition to these tests there are included the results of the greenhouse experiments on the Clinton silt loam from Scott county and Henry county, the results on the Tama silt loam from Marshall county and Cedar county and the results on the Carrington loam from Clinton county. These experiments were carried out on soil types which are the same as those occurring in Dubuque county and hence the results may be considered applicable to that county.

In all the greenhouse experiments the fertilizers tested were employed in the same amounts as are used in the field experiments. Thus the results obtained in the greenhouse may be considered to indicate quite accurately the effects of the same fertilizer in the field. The treatments used include manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure was added at the rate of eight tons per acre, sufficient lime was supplied to neutralize the acidity of the soil and two tons additional were added. Rock phosphate was applied at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 complete commercial

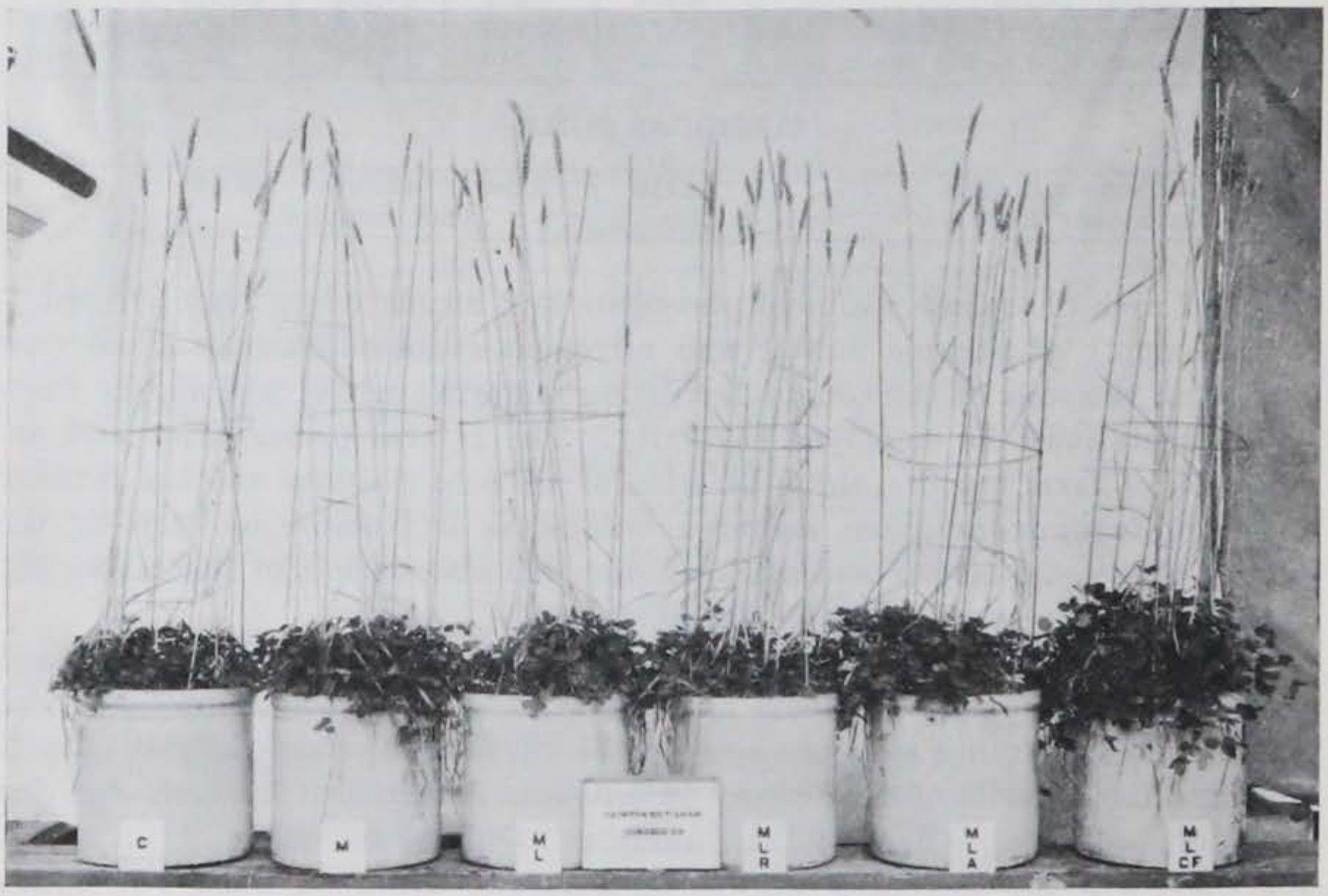


Fig. 4. Greenhouse experiment with wheat and clover on Clinton Silt Loam, Dubuque county.

fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown on the plots, the clover being seeded about one month after the wheat was up. In the two experiments on the soils from Dubuque county only the wheat yields were secured. In two of the experiments only the clover yields are given.

RESULTS ON CLINTON SILT LOAM

The results secured in the experiment on the Clinton silt loam from Dubuque county are given in table VII, the figures being the averages of the yields of wheat grain in grams on the duplicate pots. The addition of manure brought about a distinct increase in the wheat and lime with manure gave a large

TABLE VII. GREENHOUSE EXPERIMENT CLINTON SILT LOAM, DUBUQUE COUNTY

Pot No.	Treatment	Weight wheat grain in grams
1	Check	6.087
2	Manure	6.971
3	Manure+lime	8.167
4	Manure+lime+rock phosphate	9.224
5	Manure+lime+acid phosphate	9.355
6	Manure+lime+complete commercial fertilizer	8.400

gain. It is not usually expected that lime will increase yields of wheat but in this case a distinct gain in the crop was noted. Both the rock phosphate and acid phosphate brought about large increases in the yield of grain, the acid phosphate showing up slightly better than the rock. The complete commercial fertilizer did not produce as large an effect as the phosphates.

It seems apparent that manure is a valuable fertilizer for use on this soil and the addition of lime with the manure may bring about a considerable increase in the yields of general farm crops, even of such crops as wheat which are not usually particularly sensitive to acidity. Phosphate fertilizers apparently may produce a large effect on the yield of wheat and will undoubtedly have similar effects on other crops. The complete commercial fertilizer used in this test is evidently not as desirable for application as the use of a phosphate. The results do not indicate positively whether or not acid phosphate or rock phosphate should be used, but there are indications that acid phosphate is somewhat preferable.

RESULTS ON TAMA SILT LOAM, LIGHT COLORED PHASE

The results secured on the light colored phase of the Tama silt loam from Dubuque county are given in table VIII. The addition of manure brought about a large effect on the wheat grown on this soil. Lime with manure gave

TABLE VIII. GREENHOUSE EXPERIMENT TAMA SILT LOAM (LIGHT COLORED PHASE) DUBUQUE COUNTY

Pot No.	Treatment	Weight wheat grain in grams
1	Check	3.073
2	Manure	5.296
3	Manure+lime	7.651
4	Manure+lime+rock phosphate	7.997
5	Manure+lime+acid phosphate	8.655
6	Manure+lime+complete commercial fertilizer	9.397

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

a still further pronounced increase which is particularly interesting as wheat does not usually respond to applications of lime. The two phosphates both increased the wheat grain, the acid phosphate showing up very much better than the rock phosphate. The complete commercial fertilizer gave larger effects than either of the phosphates. The gain over the acid phosphate was hardly sufficient, however, to make the use of the complete fertilizer more profitable.

The results of this greenhouse experiment indicate very definite benefits from the application of manure to this soil and apparently this material should be liberally applied. The addition of lime along with manure brought about distinct increases in the wheat yield and would undoubtedly have large effects on other crops. The application of a phosphate fertilizer seems to be of distinct value on this soil, the acid phosphate having a much greater effect than the rock phosphate. It would seem that the acid phosphate would probably be more desirable for use but definite conclusions along this line should not be drawn until more complete experimental data are secured. While the complete commercial fertilizer used in this test gave somewhat better results than the phosphates the latter materials would probably prove more profitable for use.

RESULTS ON CLINTON SILT LOAM FROM SCOTT COUNTY

The results from the greenhouse experiment on the Clinton silt loam from Scott county are given in table IX, the average yields of both the wheat and clover being shown.

Manure brought about an increase in the wheat yield and had a very pronounced effect on the clover. Lime with manure gave a further increase in the wheat but showed no effect on the clover. This is contrary to the usual results as lime ordinarily increases the clover yield to a large extent and may have but little effect on crops like wheat. The acid phosphate increased the

TABLE IX. GREENHOUSE EXPERIMENT, CLINTON SILT LOAM, SCOTT COUNTY

Pot No.	Treatment	Wheat grain in grams	Clover in grams
1	Check	8.34	25.5
2	Manure	8.55	49.5
3	Manure+lime	9.30	47.0
4	Manure+lime+rock phosphate	8.49	58.0
5	Manure+lime+acid phosphate	9.97	46.0
6	Manure+lime+complete commercial fertilizer	9.27	49.5

wheat yield to a considerable extent but had little effect on the clover. Rock phosphate on the other hand had no influence on the wheat but brought about a distinct effect on the clover. The complete commercial fertilizer showed little effect on either crop.

These results very largely confirm those obtained on the Clinton silt loam from Dubuque county. They show the beneficial effect of manure on this soil and they indicate the value of lime, which may be evidenced on the legume crop or other crops of the rotation. There are indications that the addition of a phosphate fertilizer might be of distinct value. Apparently it is not possible to choose between the two phosphates as sometimes the acid phosphate seems preferable while at other times rock phosphate gives the largest influence. The complete fertilizer does not seem to be as desirable for use as the phosphates.

RESULTS ON THE CLINTON SILT LOAM FROM HENRY COUNTY

The results secured in the greenhouse experiment on the Clinton silt loam from Henry county appear in table X. Only the clover yields are given in the table as the results for the wheat were abnormal.

The application of manure brought about a profitable effect on the clover and lime with manure increased the yield to a large extent. The rock phosphate had no apparent influence but the acid phosphate gave a distinct gain in the crop. The complete commercial fertilizer had less influence.

Again these results confirm those secured on the same soil type in Dubuque county. They show the beneficial effect of manure and very definitely indicate the increase which may follow the application of lime to a crop like clover. Apparently phosphate fertilizers may be of considerable value and

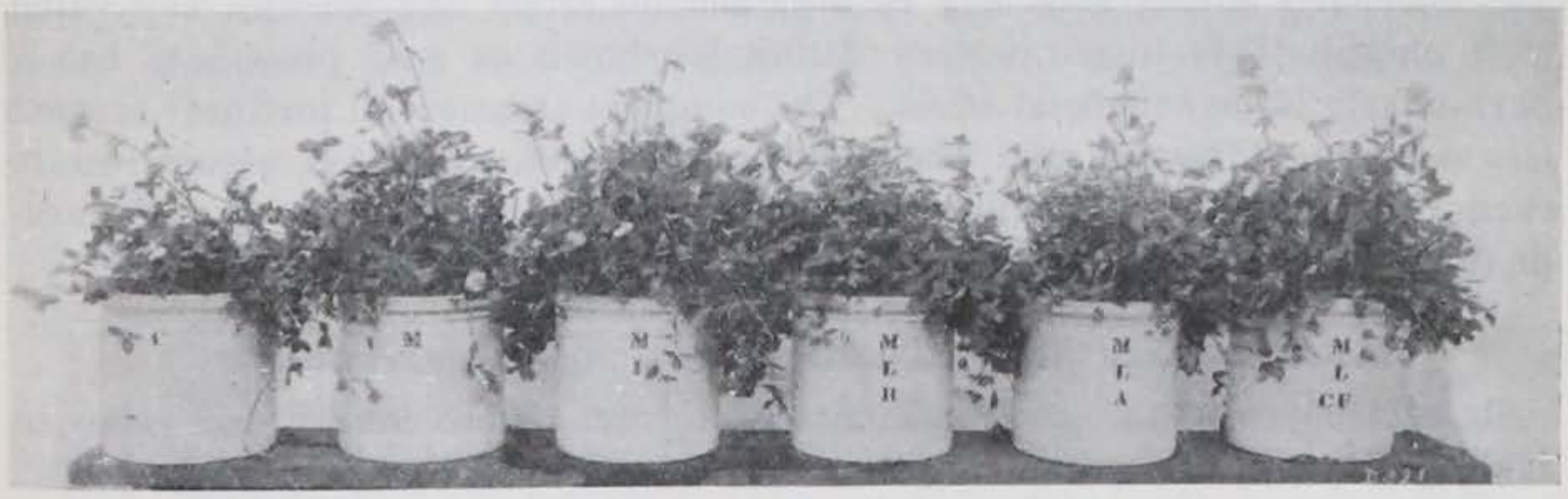


Fig. 6. Clover pot culture on Clinton silt loam.

TABLE X. GREENHOUSE EXPERIMENT, CLINTON SILT LOAM, HENRY COUNTY

Pot No.	Treatment	Weight of clover in grams
1	Check	35.0
2	Manure	40.0
3	Manure+lime	56.0
4	Manure+lime+rock phosphate	49.0
5	Manure+lime+acid phosphate	63.0
6	Manure+lime+complete commercial fertilizer	56.0

acid phosphate seems to be somewhat preferable. Further results are of course necessary before a definite choice between the two phosphates can be made. The complete commercial fertilizer had less effect than the phosphates and hence could not be considered as desirable for use.

RESULTS ON THE TAMA SILT LOAM FROM MARSHALL COUNTY

The data obtained in the experiment on the Tama silt loam from Marshall county are given in table XI. In this test manure brought about a distinct effect on the wheat crop but had little influence on the clover. Lime in addition to manure increased both crops showing a slight effect on the wheat but a large influence on the clover. Rock phosphate and acid phosphate both

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

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

gave increases in the two crops, the acid phosphate having very much larger effects than the rock phosphate. The latter gave a distinct increase in clover and had a small effect on the wheat. The acid phosphate produced a very large increase in clover and had a distinct beneficial effect on the wheat. The complete commercial fertilizer had a beneficial effect on both crops but it showed less influence than the acid phosphate, proving, however, somewhat superior to the rock phosphate in the case of the clover crop.

Apparently this soil will respond to applications of manure and the use of lime is very desirable as large increases in the legume crop are secured and beneficial effects may also be obtained on crops like wheat. The value of a phosphate fertilizer is very definitely shown as acid phosphate has a particularly large beneficial effect. The complete commercial fertilizer seemed less desirable than the acid phosphate but it gave somewhat better results than rock phosphate. Definite recommendations regarding the use of phosphates on this soil cannot be given until more complete data are secured.

RESULTS ON THE TAMA SILT LOAM FROM CEDAR COUNTY

Results obtained on the Tama silt loam from Cedar county are given in table XII. Only the green weight of the clover crop is given and the wheat yields were not secured.

TABLE XII. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, CEDAR COUNTY

Pot No.	Treatment	Green weight clover in grams
1	Check	4.53
2	Manure	43.09
3	Manure+lime	58.96
4	Manure+lime+rock phosphate	58.96
5	Manure+lime+acid phosphate	106.59
6	Manure+lime+complete commercial fertilizer	111.13

The large beneficial effect of manure is indicated in these results and the value of lime on the legume crop is also definitely shown. Rock phosphate had apparently little effect but the acid phosphate and complete commercial fertilizer brought about large increases, the complete fertilizer having slightly larger effects than the acid phosphate.

These results confirm those secured on the same soil type in Dubuque county and they show the value of applications of manure to this type and that lime should be applied if the best growth of legumes is to be secured. The use of a phosphate fertilizer may be distinctly beneficial and apparently acid phosphate is far more desirable than rock phosphate. A complete commercial fertilizer does not appear to bring about results which are sufficiently greater than those produced by the acid phosphate to warrant the application of the more expensive material.

RESULTS ON THE CARRINGTON LOAM FROM CLINTON COUNTY

In table XIII there appear the results obtained in the experiment on Carrington loam from Clinton county. The application of manure to this soil brought about an increase in the wheat and had a very large beneficial effect on the clover. Lime with manure increased the yield of both crops showing not only a large effect on the clover but a very pronounced beneficial effect on the wheat. The phosphate fertilizers both increased the clover, the acid phosphate showing up the best but it had no influence on the wheat while the rock phosphate gave a distinct gain. The complete commercial fertilizer increased the wheat but had little effect on the clover.

It is apparent from these results that this soil should receive liberal applications of manure and that lime should be applied not only because of its beneficial effect on the legume crops but also because it brings about increases in other general farm crops. Phosphate fertilizers may prove of distinct value on this soil but the data does not permit of a choice between rock phosphate and acid phosphate. The complete commercial fertilizer

TABLE XIII. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, CLINTON COUNTY

Pot No.	Treatment	Wheat grain in grams	Clover in grams
1	Check	7.27	6.0
2	Manure	7.50	35.0
3	Manure+lime	8.75	57.0
4	Manure+lime+rock phosphate	9.17	58.0
5	Manure+lime+acid phosphate	7.77	63.5
6	Manure+lime+complete commercial fertilizer	9.32	56.5

seems to be of less value than the acid phosphate or the rock phosphate and apparently one of the latter materials should be employed.

FIELD EXPERIMENTS

Field experiments have been laid out in Dubuque county only recently and hence no results from these tests are yet available for use. Data must be secured over a period of years before conclusions should be drawn from them. Results from these fields in Dubuque county will be published later in a supplementary report. Field tests have been under way however in some other counties for several years on soil types which occur in this county. The results of some of these experiments will be discussed here as they are undoubtedly pretty definitely indicative of what may be expected on the same soils in this county.

These field tests are all laid out on land which is representative of a particular soil type and the plots are 155′7″ by 28′ in size making them one-tenth of an acre. They are permanently located by the installation of corner stakes and all precautions are taken in the application of fertilizers and the harvesting of crops that the results may be accurate.

The fertilizing materials which are applied include limestone, rock phosphate, acid phosphate, and a complete commercial fertilizer either with manure or with crop residues, the former representing the livestock system of farming and the latter the grain system. Manure is applied at the rate of eight tons per acre once in a four-year rotation. Limestone is added in amounts sufficient to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is used at the rate of 2,000 pounds per acre once in a four-year rotation, acid phosphate at the rate of 200 pounds per acre annually and until 1923 a 2-8-2 complete commercial fertilizer was used at the rate of 300 pounds per acre annually. The new standard 2-12-2 brand is now being employed at the rate of 267 pounds per acre annually, thus supplying the same amount of phosphorus as that contained in the 200 pounds of acid phosphate.

On the grain system plots all of the crop residues are turned under in the soil. The second crop of clover is plowed under and sometimes the first crop is cut and allowed to remain on the land to be plowed under with the second. The corn stalks are cut with the disc or stalk cutter and plowed under. The straw from the small grains is all returned to the land, application being made at some convenient time.

THE PRINCETON FIELD

The field experiment in Scott county on the Princeton Field is on the Clinton silt loam and the results of this experiment are given in table XIV. The addition of manure showed a large increase on the corn in 1920 and 1923 and on the clover in 1922, it also benefited the oats in 1921, but it had no large effect on the crops in 1918 and 1919. Lime with manure increased the crop yields in every case showing beneficial effects not only on the clover but on corn, oats, and wheat. The phosphates with manure and lime proved of value in most cases. Increases were noted from both materials on the clover

TABLE XIV. FIELD EXPERIMENT, CLINTON SILT LOAM, SCOTT COUNTY, PRINCETON FIELD—SERIES I

Plot No.	Treatment	1918 W. Wheat bu. per A.	1919 Corn bu. per A.	1920 Corn bu. per A.	1921 Oats bu. per A.	1922 Clover tons per A.	1923 Corn bu. per A.
1	Check	40.7	69.3	61.8	27.7	1.41	54.0
2	Manure	37.4	67.6	68.3	28.4	1.93	63.2
3	Manure+lime	43.0	68.2	70.6	32.1	2.13	70.2
4	Manure+lime+rock phosphate	47.4	67.8	73.5	31.9	2.25	72.5
5	Manure+lime+acid phosphate	45.2	64.0	70.8	35.1	2.29	73.2
6	Manure+lime+complete commercial fertilizer	37.3	68.4	73.0	36.4	2.34	68.1
7	Check	31.7	57.0	57.5	24.4	1.60	53.0
8	Crop residues	54.1	52.6	58.6	29.6	1.47	55.2
9	Crop residues+lime	31.7	62.4	67.3	29.7	2.14	61.8
10	Crop residues+lime+rock phosphate	35.0	64.1	68.7	29.8	2.28	65.0
11	Crop residues+lime+acid phosphate	31.7	66.6	61.5	31.1	2.18	68.0
12	Crop residues+lime+complete commercial fertilizer	36.2	65.2	69.5	30.8	White Mildew	70.1
13	Check	28.2	59.3	59.5	25.5		58.6

in 1922, on the corn in 1923 and on the wheat in 1918. The acid phosphate proved beneficial to the oats in 1921. The rock phosphate increased the corn yield in 1920. The acid phosphate seems slightly superior to the rock phosphate but the differences are not large enough to be distinctive. The complete commercial fertilizer had slightly larger effects than the phosphates in four cases but showed less influence on the wheat in 1918 and on the corn in 1923. The differences were too small in every case to warrant the use of the material.

The crop residues showed increases in a few instances the effect being noticed on the oats in 1921 and on the corn in 1923. Lime with the residues gave large effects on the clover and on the corn in 1919, 1920 and 1923 but had little effect on the oats and none on the wheat. The phosphates with the crop residues and lime brought about increases in crop yields in most cases, altho no large effects were noted. The rock phosphate gave the largest effect on the corn in 1923, showing gains also on the other crops. The acid phosphate increased the corn in 1919, the oats in 1921 and the corn in 1923 to the greatest extent. The complete commercial fertilizers had slightly larger effects than the phosphates in several cases but the differences were not large enough to warrant the use of the more expensive material.

It is apparent from the results of this experiment that the Clinton silt loam will respond to applications of manure, lime and phosphates. Manure should be applied in liberal amounts, lime should be added to neutralize the acidity especially if legumes are to be grown and a phosphorus fertilizer should undoubtedly be employed. There are indications that acid phosphate would be more profitable than the rock phosphate but further experimental results are necessary before definite conclusions can be drawn regarding the relative

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TABLE XV. FIELD EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY, HUDSON FIELD—SERIES II

Plot No.	Treatment	1918 Corn bu. per acre	1919 Oats bu. per acre	1920 Corn bu. per acre	1921 Corn bu. per acre	1922 Oats bu. per acre	1923 Corn bu. per acre
1	Check	45.8	47.6	53.2		44.8	54.0
2	Manure	49.3	54.7	62.8	Cut	53.1	59.6
3	Manure+lime	54.4	59.2	67.4	and	59.6	65.2
4	Manure+lime+rock phosphate	56.5	64.9	73.3	put in silo	58.1	61.4
5	Manure+lime+acid phosphate	57.4	62.2	73.3		53.2	59.6
6	Manure+lime+complete commercial fertilizer	58.5	57.5	72.4		62.2	68.4
7	Check	56.9	62.2	44.0		41.4	54.8
8	Crop residues	54.7	62.2	65.2		49.0	53.1
9	Crop residues+lime	57.9	64.6	71.3		62.4	66.7
10	Crop residues+lime+rock phosphate	62.8	58.1	74.9		59.6	65.7
11	Crop residues+lime+acid phosphate	55.6	55.8	74.9		64.4	62.8
12	Crop residues+lime+complete commercial fertilizer	52.5	57.5	74.1		71.3	62.8
13	Check	54.5	57.0	71.3		59.7	50.2

value of these two materials. Apparently one of the phosphates would be preferable to a complete commercial fertilizer, as the latter will not give results which are sufficiently greater to warrant the higher cost of the material.

THE HUDSON FIELD

The results secured on the Tama silt loam on the Hudson Field in Black Hawk county are given in table XV. Crop yields have been secured on this field for five years. In the year 1921 no yields were recorded as the corn was cut and put in the silo by the co-operator. Manure brought about a profitable effect on all of the corn and oats crops on this field, the average increases being quite definite in all cases. Lime with manure gave further increases, the gains being surprisingly distinct as corn and oats are not usually sensitive to acidity in soils and the addition of lime often has little effect. Increases from the use of rock phosphate and acid phosphate were secured in 1918, 1919 and 1920, but these materials had little influence in 1922 and 1923. In the years when beneficial effects were secured, there was little difference in the effect of the two materials and no choice between them could be considered as indicated. The complete commercial fertilizer showed a beneficial effect on the crops in all cases except on the oats in 1919. Beneficial effects were very little if at all greater than those brought about by the phosphates and hence it would seem that the latter materials are more desirable for use.

Crop residues showed some effects on the corn in 1920 and on the oats in 1922, but in general brought about no distinct influence. The addition of lime, as was true in the case of the application of lime with manure gave

distinct increases in the crops each year, the largest effects being noted on the oats in 1922 and on the corn in 1923. The rock phosphate gave increases in two cases but in general had little effect. The acid phosphate likewise brought about increases in two instances, but the differences in crop yields were small. The complete commercial fertilizer had no greater effect than the phosphates except in one case and then the difference was not large.

These results indicate that the Tama silt loam will respond very definitely to the application of manure and this material should be applied in liberal amounts. Lime with manure is of large value, bringing about very definite increases even on corn and oats. The addition of a phosphate with lime and manure may prove profitable and farmers should test the value of rock phosphate and acid phosphate to determine the need of phosphorus on their soils and also to learn which material should be employed. A complete commercial fertilizer cannot be recommended in preference to a phosphate as the latter will apparently give larger economic returns. The use of lime under a grain system of farming with crop residues is very desirable and it seems possible that a phosphate fertilizer might be used under such conditions with profit.

THE JESUP FIELD

The results obtained on the Carrington loam on the Jesup field in Black Hawk county are given in table XVI. The application of manure to this soil gave increases in crop growth except in the case of the oats in 1918 and 1923. The application of lime along with the manure increased the crop yields in all cases except one. Rock phosphate and acid phosphate both proved of value on the corn in 1922 and on the oats in 1923, but the materials

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

Plot No.	Treatment	1918 Oats bu. per acre	1919 Clover tons per acre	1920 Timothy and clover tons per A.	1921 Corn bu. per acre	1922 Corn bu. per acre	1923 Oats bu. per acre
1	Check	71.9	1.17	0.50	58.7	51.4	31.7
2	Manure	71.6	2.08	0.85	72.8	65.6	29.4
3	Manure+lime	83.1	1.92	1.20	77.6	71.1	37.3
4	Manure+lime+rock phosphate	81.8	1.86	1.15	78.1	73.4	41.8
5	Manure+lime+acid phosphate	76.1	2.22	1.12	75.5	73.4	45.3
6	Manure+lime+complete commercial fertilizer	77.2	2.80	1.25	78.7	77.6	44.2
7	Check	60.8	1.38	0.47	54.0	53.7	34.0
8	Crop residues	64.0	1.36	0.52	56.5	56.0	38.3
9	Crop residues+lime	64.9	1.15	0.42	46.4	52.0	36.3
10	Crop residues+lime+rock phosphate	63.6	1.53	0.42	60.8	60.8	38.7
11	Crop residues+lime+acid phosphate	62.5	1.53	0.60	67.6	62.6	38.3
12	Crop residues+lime+complete commercial fertilizer	75.7	1.77	0.70	72.8	70.2	38.3
13	Check	67.8	1.20	0.65	60.2	55.4	34.0

did not show any large effect on the crops grown in the earlier years except the acid phosphate on the clover in 1919. The complete commercial fertilizer had no greater effect than the phosphates except on the clover in 1919, when this material showed an increase greater than that brought about by the acid phosphate.

There was very little evidence of value from the crop residues tho slight increases were noticed in most cases. Lime with the crop residues likewise had little influence. The phosphates both brought about distinct gains in crop yields with all of the various crops except the oats in 1918. The acid phosphate seemed slightly superior to the rock phosphate and there was very little difference in the effect of the two materials. The complete commercial fertilizer was slightly superior to the phosphates in several cases, the differences being particularly noticeable on the corn and clover.

It is apparent from these results that manure is a very valuable fertilizer for use on this soil and the addition of lime is necessary when the soil is acid. Phosphate fertilizers may be very desirable for use as there are indications of value from the application of rock phosphate or acid phosphate. A choice between the two materials cannot be made from the data at present available. The complete commercial fertilizer apparently is not any more valuable than acid phosphate, and hence cannot be recommended as any more desirable for use.

THE WAVERLY FIELD

The results obtained on the Carrington loam on the Waverly field No. I, Series I in Bremer county are given in table XVII. The application of manure increased the yields of all of the crops grown on this soil except the

TABLE XVII. FIELD EXPERIMENT, CARRINGTON LOAM, BREMER COUNTY, WAVERLY FIELD—NO. I SERIES I

Plot No.	Treatment	1918 Oats bu. per acre	1919 Clover tons per acre	1920 Corn bu. per acre	1921 Oats bu. per acre	1922 Corn bu. per acre	1923 Oats bu. per acre
1	Check	46.6	1.40	85.3	36.8	54.9	32.8
2	Manure	57.2	1.84	89.0	38.9	57.6	31.7
3	Manure+lime	49.1	2.02	87.8	35.4	60.5	29.4
4	Manure+lime+rock phosphate	67.0	2.10	94.0	46.5	64.1	34.0
5	Manure+lime+acid phosphate	62.5	3.10	101.5	45.2	74.9	37.3
6	Manure+lime+complete commercial fertilizer	58.5	2.84	94.2	40.7	81.0	38.3
7	Check	50.4	1.48	83.8	33.5	61.1	34.0
8	Crop residues	52.6	1.90	81.6	35.3	60.8	27.2
9	Crop residues+lime	57.2	1.94	96.3	42.4	73.6	30.6
10	Crop residues+lime+rock phosphate	50.7	2.32	97.8	48.6	70.6	36.3
11	Crop residues+lime+acid phosphate	56.8	2.52	101.0	37.7	64.5	29.4
12	Crop residues+lime+complete commercial fertilizer	48.1	2.68	104.5	45.8	78.1	35.2
13	Check	48.9	1.56	84.3	34.7	59.2	31.7

oats in 1923, increases being very pronounced in most cases. The application of lime along with manure proved of value in several cases, the increases being particularly noticeable on the clover. Rock phosphate and acid phosphate proved of distinct value in all cases on this soil, the acid phosphate showing up very much better than the rock phosphate in all cases but one. In fact increases brought about from the use of acid phosphate on this soil are very large. The complete commercial fertilizer was less beneficial than the acid phosphate in all cases but one and hence could not be considered as desirable for general use.

Crop residues had little effect on the yields on this soil. The addition of lime brought about quite large increases in all cases even on the corn and small grains. Again the addition of rock phosphate and acid phosphate proved of value, large increases being brought about in several cases. The complete commercial fertilizer had somewhat greater effects than the acid phosphate with most of the crops but the differences were not very large. This material could not be considered as any more desirable for use than the acid phosphate.

These results very largely confirm those secured on the Jesup field, indicating the value of manure and lime on this soil and suggesting the possibility of large crop increases resulting from the application of either rock phosphate or acid phosphate, the latter material apparently being somewhat preferable for use. The complete commercial fertilizer seems less desirable than the acid phosphate.

AVERAGE RESULTS ON THE TAMA SILT LOAM

Average results secured from all of the field experiments in the state on the Tama silt loam are given in table XVIII. Manure brought about increases

TABLE XVIII. TAMA SILT LOAM. AVERAGE CROP YIELDS AND INCREASES DUE TO FERTILIZER TREATMENT. IOWA EXPERIMENT FIELDS

Treatment	Corn*		Oats*	
	Bu. per acre	Increase from treatment bu. per acre	Bu. per acre	Increase from treatment bu. per acre
Check	63.3	....	46.0	....
Manure	69.6	6.3	49.4	3.4
Manure+lime	71.8	8.5	56.3	10.3
Manure+lime+rock phosphate	77.7	14.4	58.6	12.6
Manure+lime+acid phosphate	75.3	12.0	56.7	10.7
Manure+lime+complete commercial fertilizer	73.7	10.4	62.9	16.9
Crop residues	69.7	6.4	47.0	1.0
Crop residues+lime	71.8	8.5	57.9	11.9
Crop residues+lime+rock phosphate	74.4	11.1	58.9	12.9
Crop residues+lime+acid phosphate	75.7	12.4	63.3	17.3
Crop residues+lime+complete commercial fertilizer	72.7	9.4	68.0	22.0

*The corn yields are the averages of 3 years results on 2 fields. The oats yields are the averages of 2 years results on 2 fields.

in both corn and oats. Lime with manure had large effect on both of these crops. Rock phosphate and acid phosphate produced large increases, the differences between the effect of the two materials being rather slight but somewhat in favor of the rock phosphate. The complete commercial fertilizer had less effect than the phosphates on corn but proved somewhat better on the oats. Crop residues had very little effect on the various crops but lime again gave distinct increases in both crops. Phosphates gave increases in both cases, the acid phosphate showing up somewhat better than the rock phosphate. The complete commercial fertilizer again gave less effect than the phosphates on the corn but had greater effect on the oats.

The results as a whole indicate the value of lime, manure and phosphorus on the Tama silt loam. With crop residues the acid phosphate seems to be better than the rock phosphate while in the presence of manure the rock phosphate seems to give quite satisfactory results both on the corn and on the oats. The complete commercial fertilizer had less effect than the phosphates on the corn but gave greater increases on the oats but they were not large enough in any case to make the use of this material more profitable than the acid phosphate. The testing of phosphate fertilizers on this soil is very desirable.

AVERAGE RESULTS ON THE CARRINGTON LOAM

Average yields secured on all of the experiment fields on the Carrington loam are given in table XIX. The application of manure to this soil brought about large increases in the corn, oats and clover. Lime with manure proved of value on these three crops showing quite as large effects on the corn and

TABLE XIX. CARRINGTON LOAM. AVERAGE CROP YIELDS AND INCREASE DUE TO FERTILIZER TREATMENT. IOWA EXPERIMENT FIELDS

Treatment	Corn*		Oats*		Clover*	
	Average yield bu. per acre	Increase for treatment bu. per acre	Average yield bu. per acre	Increase for treatment bu. per acre	Average yield tons per acre	Increase for treatment tons per acre
Check	51.9	....	43.6	....	1.25	....
Manure	58.8	6.9	49.6	6.0	1.38	0.13
Manure+lime	62.6	10.7	53.0	9.4	1.57	0.32
Manure+lime+rock phosphate	66.0	14.1	62.3	18.7	1.97	0.72
Manure+lime+acid phosphate	66.3	14.4	60.8	17.2	2.27	1.02
Manure+lime+complete commercial fertilizer	66.8	14.9	62.4	18.8	2.29	1.04
Crop residues	54.7	2.8	47.3	3.7	1.37	0.12
Crop residues+lime	57.5	5.6	49.3	5.7	1.41	0.16
Crop residues+lime+rock phosphate	61.8	9.9	51.2	7.6	1.80	0.55
Crop residues+lime+acid phosphate	62.4	10.5	52.7	9.1	1.94	0.69
Crop residues+lime+complete commercial fertilizer	64.2	12.3	58.2	14.6	2.02	0.77

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

small grain as on the clover. The application of rock phosphate and acid phosphate proved of profit on the various crops, the results being very similar on corn and oats but the acid phosphate showed up much better on the clover. The complete commercial fertilizer gave results very much the same as those produced by the phosphates on the corn and oats and the same as the results with the acid phosphate on the clover. Crop residues gave slight increases and the use of lime along with the residues proved of distinct value. The two phosphates increased the crop yields, the acid phosphate showing up better than the rock in every case. The complete commercial fertilizer brought about increases which were somewhat larger than those occasioned by the acid phosphate.

On this soil the addition of manure is evidently very desirable and lime should be employed to remedy the acid conditions. The application of phosphorus fertilizers will undoubtely prove of profit and tests of rock phosphate and acid phosphate are very desirable. The complete commercial fertilizer does not seem to be of any greater value than the phosphates when applied with manure and lime. In the grain system of farming when the fertilizer is applied with crop residues and lime, acid phosphate seems distinctly superior to the rock phosphate and the complete commercial fertilizer gave better results than acid phosphate. The differences are considerable and it may be that under the grain system of farming a complete fertilizer might prove of large value. Tests on individual farms are recommended.

THE NEEDS OF DUBUQUE COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD EXPERIMENTS

The fertilizer needs of the soils of Dubuque county are indicated by the laboratory, greenhouse and field experiments which have just been discussed. While the field experiments described were not located in this county, the soil types are the same as those appearing in Dubuque county and hence the results may be considered to indicate quite definitely the needs of Dubuque county soils. The experiments which have been started in Dubuque county have not yet been under way for a long enough time so that conclusions can be drawn from them. The results of these tests will be published later in a supplementary report.

The results secured in these adjacent counties very largely confirm the conclusions from the laboratory and greenhouse tests and they are also supported by much practical experience, hence the suggestions which are offered here may be considered as based on considerable experimental work and practical experience. No treatments are recommended which have not proven of value. It is suggested in some cases that tests be carried out on individual farms and it may be said that such tests may be readily carried out by any farmer. Many are already conducting similar tests on their farms and are securing results of large value to themselves and of general interest to farmers on the same types. The Soils Section of Iowa Agricultural Experi-

ment Station will aid any who may wish to test the needs of their own soils and directions which may be followed in carrying out such tests are given in Circular 82 of the Experiment Station.

LIMING

The soils of Dubuque county are all acid in reaction in the surface and practically all are acid in the lower soil layers as well. Hence there is need for the application of lime to practically all of the soils in the county. General farm crops and particularly legumes such as red clover and alfalfa grow best in the presence of lime. The legumes will make a very unsatisfactory growth when the soil is acid but corn and the small grains are not particularly sensitive to acidity. The addition of lime to acid soils will, however, frequently give considerable increases in the yields of these crops. Large gains are practically always secured when lime is applied on acid soils for legumes.

The addition of lime to soils proves of value because of the improvement in the physical, chemical and bacterial conditions. It is of importance chiefly because it neutralizes the acid conditions in the soil which may be quite injurious to legume growth. It also supplies the plant food constituent, calcium, which may be deficient and which is required in considerable amounts for such crops as alfalfa. The physical conditions of both heavy and light soils are improved by liming as it opens up tight, impervious soils, introducing air making them less cold and moist and in a generally better condition for the production of available plant food. Light sandy soils are improved by liming because it cements the particles together, makes the soils less open and porous and better able to retain moisture and plant food. All the desirable bacterial activities in soils are stimulated by additions of lime. There is greater decomposition of organic matter and consequently a greater production of nitrates and all other necessary plant food constituents in an available form. There may be greater fixation of free nitrogen from the air in the soil both by the free living microorganisms and by those living in association with the legumes. Hence the use of lime may aid in the maintenance of the total nitrogen content of the soil. In some instances the application of lime may be of value on acid soils because of the effect on the chemical, or the bacterial or the physical conditions, but in general the increases which are obtained in crop yields may be attributed to the effect on all conditions together.

The necessity for applying lime to the soils of Dubuque county is indicated by the lime requirement tests reported in the analyses of the soils, but there is evidence of large effects of lime on crop yields which support the indications from the analytical data. The greenhouse tests and the field experiments discussed earlier in this report show what benefits may result from the use of lime. Much farm experience also confirms the importance of the practice and liming is largely coming to be considered a fundamental soil treatment on every farm if the best growth of crops, particularly legumes, is to be secured and the soils are to be kept permanently productive.

There is considerable variation in the amount of lime needed on different soils, and wide variations will also frequently occur in soils of the same

type in different fields. The only way to determine the actual amount of lime which should be used on any particular soil is to test the need of that soil. Samples should be taken from every field and tested separately if the proper amount of lime is to be applied. The average results given in the tables should be considered merely indicative of the needs of the individual soil type. Lime should be applied on the basis of these analyses but only after the soils have been tested. Farmers may test their own soils and determine how much lime is needed on the particular area but it will probably be more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. Then they may be confident that they are applying the proper amount of lime to secure the best results.

One addition of lime to a soil will not be adequate to keep up the supply indefinitely as lime is removed from soils rather rapidly thru leaching and utilization by crops. It is considered desirable that the soil be tested at least once in a four-year rotation and that lime be applied as needed. The best results are secured when the lime is applied just preceding the legume crop of the rotation. The other crops of the rotation are also benefited but to a small extent.

It is urged that farmers of Dubuque county have their soils tested now for lime needs and that they apply the amount shown to be necessary by the tests. They should also plan on making tests at regular intervals in the future and keep up the supply of lime by regular additions. In this way they may insure the best growth of leguminous crops and may keep their soils permanently fertile. Further information regarding the use of lime on the soil and other points in connection with liming are given in Extension Bulletin 105 of the Iowa State College.

MANURING

The supply of organic matter is not particularly large in any of the soils of Dubuque county. In most of the types the supply is rather low. The Clinton silt loam for example, the most extensive type in the county is rather poorly supplied. The Tama silt loam is not very rich in this constituent, the Carrington loam likewise is rather poorly supplied and many of the minor soil types, particularly those more sandy in texture are rather lacking in organic matter content. The bottomland soils are of course, better supplied than the upland types but the amounts even in these soils are not extremely large. On the terraces, the sandy soils are low in organic matter while the heavier types are better supplied. It is apparent that the supply of organic matter should be increased in many of the soils in the county and in all cases it is very important that proper treatments be followed to maintain the supply of this material.

Farm manure is the most important fertilizer for supplying organic matter to the soil. It is also the most commonly employed. Its effects in increasing crop yields are very noticeable, in fact it brings about the largest increase in crop yields of any fertilizer which can be employed. On the lighter colored coarse textured soils the effects of the manure are particularly evi-

denced. On the heavier types, however, small additions of manure have beneficial effects and on these soils as well as on those more in need of organic matter the use of farm manure is very desirable if the soils are to be kept in the best condition for crop growth.

The value of farm manure is due to its effect on the chemical, physical and bacterial conditions in the soil. It contains a large part of the essential plant food constituents which have been removed from the soil by the crops grown and used for seed. Hence it actually lengthens the life of the soil by returning large amounts of these important plant food constituents which are apt to become deficient in the soil. The importance of manure in permanent agriculture is therefore apparent. The organic matter present in the manure improves the soil conditions chemically and physically. It makes light open soils more retentive of moisture and plant food. It opens up impervious heavy soils and brings about better air and moisture conditions and hence a better production of available plant food. Bacterial conditions in the soil are much modified by manuring because of the large numbers of bacteria supplied in the manure and also because of the stimulation in the action of the bacteria already present in the soil. Bacteria are responsible for the production of available plant food in soils and an increase in most of the organisms and their action will lead naturally to a larger supply of available plant food for crop growth.

The influence of manure on crop yields is frequently not appreciated and care is not taken to secure the largest effects from this material. Sometimes it is stored in loose piles exposed to the weather and much of the valuable constituents allowed to wash away in the drainage water. Often as much as 70 to 90 percent of the most valuable portion of the manure is thus lost before it is applied to the soil. When this occurs the effects of the manure on crop yields will be largely reduced. It should be emphasized that losses from manure thru improper storage mean an actual money loss to the farmer because of the reduced effects of the manure on crop growth. It is very important that proper precautions be taken in storing manure in order to prevent losses if it is to prove of the largest value. Occasionally it is possible to spread the manure on the land as rapidly as it is produced and when this is the case there is the least opportunity for losses to occur. However, it is not always practicable to handle the manure in this way and generally it must be stored. Various methods of storing the manure have been suggested as desirable but conditions are so variable that no one method can be recommended for all circumstances. Sometimes covered yards are used. Pits may be employed. Composting is sometimes practiced. There are other methods which are desirable under certain conditions but in general it may be said that any method will be satisfactory if the manure is kept moist and compact and well protected from the weather. Even when most carefully stored, manure undergoes losses but when these are kept at a minimum as much as 75 percent of the value of the manure may be returned to the land.

The usual application of manure is about 8 to 10 tons per acre once in a four-year rotation. It is rarely economical or desirable to apply larger amounts than this for general farm crops. Experiments have indicated that

about eight tons usually gives the largest crop effects per ton of manure. On soils which are particularly deficient in organic matter, however, larger applications may sometimes be made with profit. But it is rarely desirable to go above an application of 16 to 20 tons except where truck crops are grown. On the average livestock farm there is rarely sufficient manure to provide for even the usual 8 ton application to all of the land on the farm once every four years. Hence if larger applications are made on some areas on the farm other lands must remain untreated and will gradually decease in productivity. It seems best to distribute the manure produced rather evenly over the farm, thus securing the beneficial effects on all of the land, supplementing the applications as necessary by the use of other materials supplying organic matter, among which leguminous green manures are the most important.

The beneficial effects of manure on the soils of Dubuque county have been indicated in the greenhouse and field experiments and the experience of many farmers confirm these observations. Farm manure is certainly the most profitable fertilizing material which can be used on the soils of this county and farmers should see to it that all of the manure produced is carefully stored and uniformly distributed over their land. It should serve as the basic soil treatment and other fertilizers should be used in addition to farm manure. They will not give the best effects if the organic matter supply of the soil is low.

GREEN MANURING

As has been suggested above the production of manure may not be adequate to supply the needs of all of the soils on livestock farms and some other material supplying organic matter will be needed. On grain farms some other forms of organic matter must be utilized. In both cases the use of legume crops as green manures is very desirable. Non-legumes may sometimes be employed as green manures but in general they are less desirable. Legumes, when well inoculated, have the ability of utilizing the nitrogen of the atmosphere, hence when they are turned under in the soil as green manures they add considerable amounts of nitrogen to the soil along with organic matter. This gives them a double value. Non-legumes on the other hand while they add organic matter do not increase the nitrogen supply. There are many legumes which may be utilized as green manures and some may be chosen which will give satisfactory results under almost any climatic, soil, or rotation conditions.

Green manuring may be a very desirable practice on many of the soils in Dubuque county. It is absolutely necessary on grain farms and may give very desirable effects on livestock farms to supplement the use of farm manure. It is a practice, however, which should never be followed blindly or carelessly as it may lead to undesirable effects. If the soil is too dry, a heavy green crop turned under may prove injurious to subsequent crops because of the interference with moisture conditions. When properly practiced, however, green manuring proves most profitable. Occasionally a portion of the clover crop is turned under and when this is the case there is a partial green

manuring effect. Sometimes the first crop is cut and the second plowed under. Sometimes the seed only of the legume is removed and the remainder of the crop turned under in the soil. Very large green manuring effects may thus be secured. It seems quite desirable that the practice of green manuring at least partial green manuring be practiced quite generally in Dubuque county, and beneficial effects of the practice will be evidenced on general farm crops. It will also permit the soils to be kept well supplied with organic matter and nitrogen indefinitely. Advice regarding green manuring under special conditions will be given by the Soils Section upon request.

The proper utilization of crop residues aids materially in maintaining the supply of organic matter in the soil, and there is also some value from these materials because of the plant food constituents which they contain. When they are burned or otherwise destroyed, as is so often the case, there is an actual waste of a valuable source of fertility. On livestock farms the residues should be used for feed or bedding and returned to the soil with the manure. On grain farms they may be applied directly or the straw may be allowed to decompose partially before being plowed under. The proper use of all crop residues is very necessary on grain farms but is also important on livestock farms in order to aid in maintaining the supply of organic matter and other plant food constituents.

THE USE OF COMMERCIAL FERTILIZERS

The soils of Dubuque county are rather poorly supplied with phosphorus, the amounts present as indicated by the analyses discussed earlier in this report being rather low. The bottomland soils are somewhat better supplied than the upland types but even on these soils the content of phosphorus is inadequate for any long period of time. It seems quite evident that phosphorus fertilizers will be needed on these soils at a very early date even if they do not prove of value at the present time. There is question however, whether the soils are not lacking in available phosphorus now. When the supply of a constituent becomes as low as is the case with phosphorus in some of the soils in this county, the production of the element in an available form is very much more rapidly reduced and hence in the soils of this county it seems quite likely that there is an inadequate production of available phosphorus to supply the needs of crops. Even where there is a large amount of phosphorus present there is no assurance that there will be a large production of the element in an available form and hence even on soil which seems to be better supplied with phosphorus the application of a soluble phosphate may prove of considerable value.

Phosphorus fertilizers may therefore be considered as absolutely necessary for use in Dubuque county at some future time and regularly if the soils are to be kept productive. Furthermore, fertilizers supplying the element in an available form may be very desirable for use at the present time and in fact the results of the greenhouse and field tests, discussed earlier in this report, indicate that profitable effects may be secured from the use of certain phosphate fertilizers at the present time. Definite conclusions cannot be drawn

yet but the results do indicate the desirability of testing the value of phosphates on the soils of this county.

Acid phosphate and rock phosphate are the two phosphorus fertilizers which are most generally used on soils to supply phosphorus. Acid phosphate contains the element in an immediately available form. It is applied at the rate of 150 to 200 pounds per acre annually. The rock phosphate on the other hand contains the element in a very slowly available form and it is used at the rate of 2,000 pounds per acre once in a four-year rotation. The rock phosphate, however, is much less costly than the acid phosphate. The relative value of the two materials depends, therefore, upon the amount of crop increase secured and upon the cost of the application. The field tests which are now under way include both these fertilizers and later it is hoped that definite conclusions regarding their relative value may be reported. For the present it can merely be said that the results seem to vary under different conditions, the acid phosphate usually proving slightly superior but not in all cases.

Farmers are urged to test both materials on their own soils and thus determine for their own particular conditions which should be employed. It is comparatively easy to carry out tests on the farm and directions are given in Circular 82 of the Iowa Agricultural Experiment Station which may be followed in laying out simple field experiments. It should be emphasized that results thus far secured indicate clearly a need for phosphorus on Dubuque county soils and it seems quite likely that profitable results may be secured thru the use of phosphate on these soils.

The nitrogen content of many of the soils in Dubuque county is rather low and only in one or two cases is there any large supply of this constituent. The need of supplying nitrogen to the soils in this county regularly is evident, and the importance of increasing the amount of nitrogen in some of the soils at the present time is likewise evident.

Nitrogen gradually disappears from soils thru leaching and thru utilization by crops and some nitrogenous fertilizer must be applied if these losses are to be replaced and the supply of nitrogen maintained. When farm manure is carefully stored and applied to the land it adds considerable amounts of nitrogen and may thus serve to build up and maintain the amount of this constituent in the soil. But farm manure alone will not keep up the supply of nitrogen. An ordinary application will return only a portion of the nitrogen which has disappeared from the soil and some other nitrogenous fertilizer must be employed.

The use of legume crops as green manures is the most desirable means of supplying nitrogen to the soil. When the legumes are inoculated, they take a large part of their nitrogen from the air and hence they may serve as nitrogenous fertilizers. If they are not inoculated this utilization of nitrogen will not occur and the legume will deplete the supply in the soil just like other crops. If the legume is utilized for hay it will not serve as a nitrogenous fertilizer and the soil will not gain in nitrogen, but if part of the crop is removed there may be some nitrogen added to the soil. If only the seed is harvested the legume has a considerable effect in supplying nitrogen, but the

largest value of the practice from the standpoint of supplying nitrogen can only be secured when the entire crop, thoroly inoculated, is plowed under. By the use of legumes in this way commercial nitrogenous fertilizers will not be necessary. They cannot generally be recommended for use in this county, as leguminous green manures are much more profitable. Possibly they may be used in small amounts as top dressings but for general farm crops they do not seem necessary. There is no objection to the use of commercial nitrogen carriers if tests show them to be of value but they should not be employed until such tests have been carried out.

The soils of Iowa have been shown by many analyses to be quite generally well supplied with potassium. In Dubuque county therefore it seems hardly likely that potassium fertilizers would prove of profit on general farm crops. If the supply of organic matter is kept up and the physical condition of the soil is satisfactory there should be sufficient potassium changed into an available form to keep crops well supplied. There may be cases in which a small application of an available potassium fertilizer such as the muriate or the sulphate might be of value to supply a deficiency in available potassium. But in general these materials would probably not prove profitable. Small applications of these potassium fertilizers as top dressings may sometimes be desirable but they cannot be generally recommended. In any event potassium should not be applied to the soils in this county until tests have been carried out to determine the value of the particular fertilizer. If profitable results are secured then the material may be applied to the soil with the assurance of desirable effects on crop yields.

The use of complete commercial fertilizers on Dubuque county soils can not be generally recommended at the present time. The potassium supply should be adequate for many years and the nitrogen content may be kept up more satisfactorily by the use of legumes as green manures. The deficiency in phosphorus may be supplied by the application of acid phosphate and rock phosphate. Tests which have been reported earlier indicate some increases in crop yields from the use of complete commercial fertilizers but in general acid phosphate has proven quite as satisfactory and hence more profitable for use. The complete fertilizers are more expensive than the phosphates and must therefore bring about very much larger effects on crop yields if they are to be as profitable. The indications at present are that the phosphates are more desirable for use. There may be cases however where the complete brands would give better effects. Any who are interested may readily test the relative effect of a complete fertilizer in comparison with acid phosphate and determine the relative value of the two materials for their own conditions. If profitable results are secured from the use of complete fertilizers there is no objection to applying them. Where truck crops are grown complete fertilizers may often be used with profit. For such crops specially prepared brands may be employed with profit.

DRAINAGE

The soils of Dubuque county are in general quite adequately drained. The extensive natural drainage system of the county is shown in the drainage map

given earlier in this report. There are small areas scattered thruout the county, however where drainage is poor and in these areas, tiling is very desirable. Several of the terrace and bottomland soils are poorly drained, the latter of course being subject to overflow. If the best crops are to be secured wet land must be thoroly drained. This is the first treatment needed and other treatments may be of little value unless the land has been tiled. The laying of tile in some areas in Dubuque county is very desirable and would undoubtedly bring about profitable effects. The installation of tile may mean a rather considerable expense but the increased crop yields secured always more than warrant the outlay. Care should be taken on many of the soils in Dubuque county that adequate drainage is provided.

THE ROTATION OF CROPS

The continuous growth of any one crop very rapidly reduces the fertility of the soil and it has been found by experiments and farm experience that a rotation of crops prevents such a rapid reduction in fertility. Frequently an attempt is made to grow the same crop every year because of the value of the crop, but this is always disastrous. Even when crops with less money value are used in the rotation the income secured over a period of years will be greater where the rotation is practiced than where the same crop is grown constantly.

Some rotation should always be selected and followed on every soil if the land is to be kept permanently productive. No particular rotation can be suggested for use under all conditions in Dubuque county and no special studies have been made of rotations but from among the rotations suggested below some one may be chosen which should be satisfactory for almost any conditions. In fact almost any rotation may be selected provided it contains a legume crop and the money crop. The following are suggested rotations for use in the state.

1. SIX-YEAR ROTATION

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

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

2. FOUR OR FIVE-YEAR ROTATION

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

3. FOUR-YEAR ROTATION WITH ALFALFA

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

4. FOUR-YEAR ROTATIONS

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

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

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

5. THREE-YEAR ROTATIONS

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

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

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

THE PREVENTION OF EROSION

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

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

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

The careless management of land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is

very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

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

Erosion occurs to a considerable extent in Dubuque county. The Clinton silt loam and particularly the steep phase Clinton and the Carrington, Shelby and Lindley soils are all more or less eroded. There is some surface washing on the Tama soils but these are less severely injured than the other uplands. In many cases much of the surface soil has been washed away and particularly in the Clinton series there may be an extensive occurrence of gullies. It is very necessary that some precautions be taken in this county to protect the various soils from the injurious effects both of surface washing and of gully formation.

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

EROSION DUE TO DEAD FURROWS

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

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

"Staking In."—The method of "staking in" is better as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point up-stream.

Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru, but holding the fine soil.

Earth Dams.—Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES

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

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

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

A modification of this system of "staking in" which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of four to ten feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed upstream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of

posts will depend of course upon the size of the gully. These posts should be set well into the ground and spaced about four feet apart, being arranged in a V-shape with the point downstream and lower in the center than at the sides of the ditch. This modification of the "staking in" method is proving very satisfactory.

The Straw Dam.—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used. The pile should be made so large that it will not wash out readily when its gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving of time, labor and inspection.

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

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

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

the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially the larger gullies.

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

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

The Woven Wire Dam.—The use of woven-wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for the prevention of erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod Strips.—The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and it might be employed to advantage in many other cases.

The Concrete Dam.—One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage.—The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

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

BOTTOMLANDS

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

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

Trees.—Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

HILLSIDE EROSION

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

Use of Organic Matter.—Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw and corn stalks may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

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

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

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

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

INDIVIDUAL SOIL TYPES IN DUBUQUE COUNTY*

There are 18 individual soil types in Dubuque county and these with the steep phase of the Clinton silt loam, the light colored phase of the Tama silt loam, the colluvial phase of the Wabash stony silt loam and the area of river-wash make a total of 22 soil areas. They are divided into five groups according to their origin and location. These groups are drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils.

DRIFT SOILS

There are five drift soil types in the county, classified in the Carrington, Shelby, Clyde and Lindley series. Together they cover 9.6 percent of the total area of the county.

CARRINGTON LOAM (1)

The Carrington loam is the most extensive drift soil in the county and the sixth largest type. It occurs in the western and southwestern parts of the county chiefly in Dodge, Cascade, Taylor, and Prairie Creek townships. The largest areas are found around Farley, east of Worthington and in the vicinity of Bernard. Small areas occur near Dyersville and Cascade.

The surface soil of the Carrington loam is a brown to dark brown mellow friable loam 12 to 20 inches in depth. It is underlaid by a yellowish-brown

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

loam extending to a depth of 20 to 30 inches and changing at that point into a yellowish friable sandy and gravelly clay or clay loam. Pockets of sand are frequently found at shallow depths and there are other variations in the soil and it is not at all uniform. Glacial drift consisting of a mixture of sand and gravel, clay and boulders is found at depths of three to four feet. The surface soil varies from a fine silty loam to a fine or very fine sandy loam. In the more level areas and along intermittent drainageways the surface soil is deeper and a black color occurs at lower depths. On knolls and low hills the soil is shallow and lighter in color.

In topography the type is gently rolling or nearly level. Most of the land was originally in prairie and only sparsely timbered. At the present time nearly all of it has been brought under cultivation and general farm crops, chiefly corn, oats and hay are grown. Average yields of corn amount to about 40 bushels, oats 30 to 35 bushels, timothy and clover 1 to 1½ tons per acre.

The Carrington loam will respond profitably to applications of farm manure and the use of this material in liberal amounts is strongly recommended. Large increases in crop yields are always secured by the proper use of farm manure. When farm manure is not available to apply, some leguminous crop should be turned under as a green manure, in order that the organic matter content of the soil may be built up and kept up. Incidentally the use of a legume crop as green manure will permit of the maintenance of the nitrogen supply in the soil provided the seed is inoculated. The soil is acid in reaction and should be tested and lime applied as necessary if crop growth, particularly of legumes is to be satisfactory.

Phosphorus fertilizers will undoubtedly be needed on this type in the future and in fact there are indications from experiments that the soil may often respond profitably to the use of phosphorus fertilizers at the present time. It can not be definitely stated whether acid phosphate or rock phosphate should be employed, and farmers are urged to test the use of these materials on small areas on their own farms and thus determine for their particular conditions which phosphate will prove most profitable.

In some cases the type is eroded or washed to some extent. This is very apt to occur on the more rolling to steep areas. It is very important that some method for the control or prevention of sheet washing or gullying be followed in order to protect the soil from serious injury.

SHELBY FINE SANDY LOAM (92)

The Shelby fine sandy loam is a minor type in the county covering 2.5 percent of the total area. It occurs only in the western part of the county in association with the Carrington loam and along John creek, the largest area being found along the latter creek in White Water township. Smaller areas are located northeast of Farley, southeast of Dyersville around Cascade and on west along the Maquoketa river. Quite a considerable area is located south of Worthington.

The surface soil of the Shelby fine sandy loam is a brownish to dark grayish-brown loose fine sandy loam. The soil gradually becomes lighter in color at lower depths grading into a yellowish sandy or gravelly clay loam at three

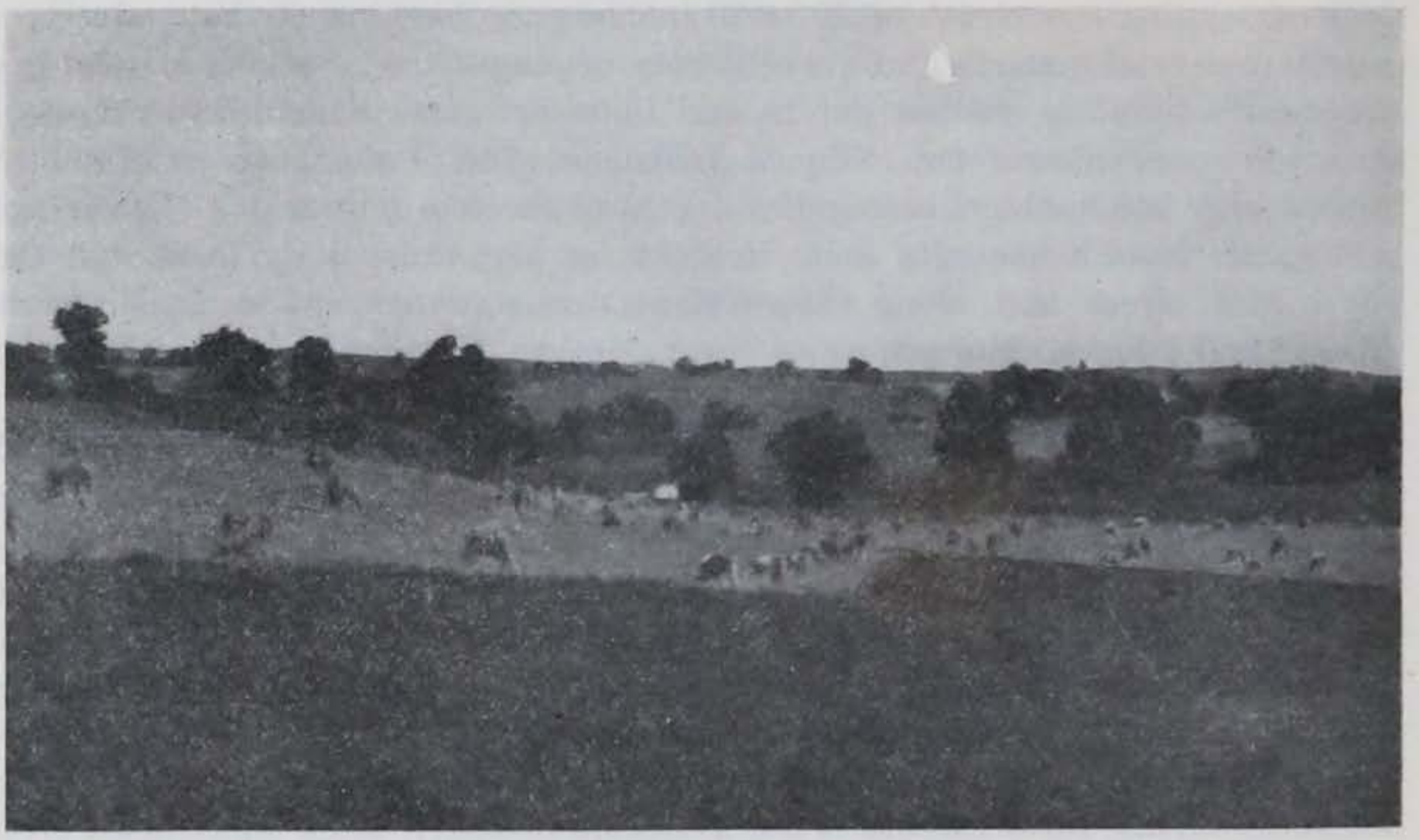

Fig. 7. Shelby fine sandy loam in Dubuque county.

feet or slightly less. The depth of the surface soil is somewhat variable and the dark color may extend from 6 to 24 inches. The subsurface soil is generally somewhat higher in content of clay than the surface soil.

The type is developed mainly on nearly level or gently sloping land and on low ridges and knolls. It is also found on moderately steep slopes along some of the larger streams. Originally the soil was forested with bur oak and white oak. In a few areas there is still some forest growth, but most of the type is now cultivated. Corn, oats, timothy and clover are the principal crops grown, the yields being somewhat lower than those secured on the Carrington and Clinton soils on the adjacent land. The soil is well drained and often excessively drained becoming somewhat drouthy in dry seasons.

Crop yields on this soil may be increased to a very large extent thru the liberal use of farm manure or the turning under of leguminous crops as green manures. The building up of the supply of organic matter is the most important treatment which the soil needs. The type is acid and in need of lime for the best growth of legumes. The phosphorus supply is low and a phosphate fertilizer would undoubtedly prove of considerable value. Tests with acid phosphate are recommended.

SHELBY LOAM (79)

The Shelby loam is a minor type in the county, covering 2 percent of the total area. It occurs in several small areas in the eastern part of the county in association with the Carrington loam and the other Shelby soils. It is found mainly in New Wine, Dodge, and Cascade townships, the largest areas being located along John creek, and southeast of Dyersville. Several smaller areas occur in Taylor, White Water, and Iowa townships.

The surface soil of the Shelby loam is a brown to dark grayish-brown mellow fine loam to a depth of 8 to 15 inches. Below that point there is a yellowish

clayey or sandy clay loam which is somewhat more compact than the surface soil. The subsoil appearing at depths of 30 to 40 inches is a yellowish mixture of sand, gravel, clay and boulders. The surface soil varies in different areas from a silt loam to a fine sandy loam. In some places there is only a thin layer of the drift resting upon limerock. These areas were too small to separate on the map.

The soil was originally forested with a thick stand of trees but at the present time the greater part of it is under cultivation. The chief crops grown are corn, oats and hay. Yields are lower than those secured on the Carrington soils and on the adjacent Clinton and Tama silt loams.

The soil is low in organic matter and should receive liberal applications of farm manure. It would also undoubtedly be improved by the turning under of leguminous crops as green manures. The supply of organic matter is particularly important to protect the soil from serious erosion. The soil is acid in reaction and should be limed before legumes are grown. It is low in phosphorus content and the addition of a phosphorus fertilizer would undoubtedly prove of value.

CLYDE SILT LOAM (84)

The Clyde silt loam is a very minor type in the county covering 0.3 percent of the total area. It occurs entirely in small narrow areas at the heads of drainageways, or in small depressed areas in the drift upland. Numerous small areas are found in the vicinity of Farley and areas occur near Worthington and Dyersville. Other small areas are found in the southwestern part of the county in the Iowan drift area.

The surface soil of the Clyde silt loam is a black and dark slaty gray compact silt loam to a depth of 4 to 10 inches. At this point its becomes a clay loam

Fig. 8. Clyde silt loam near Dyersville.

which gradually changes to a drab or mottled yellowish and gray stiff impervious clay at the lower depths. The subsoil w ich is encountered at depths of 2 to 4 feet consists of sand and gravel or a mixture of sand, gravel and clay of drift origin. Boulders are frequently found on the surface. In virgin areas there is often a thin covering of 1 to 3 inches of black muck. A small area of peat located in sections 20 and 21 of Dodge township is included with the type owing to its small extent. In this spot the peat is 5 to 6 feet in depth. In the area mapped in sections 31 and 32 in the extreme southwestern corner of the county the soil is a dark brown silty clay loam to heavy silt loam underlaid by a fine textured clay. The soil here resembles a heavy phase of the Tama silt loam but is much stiffer and more compact and more difficult to handle. It is included within the Clyde because of its small extent.

The Clyde silt loam is particularly wet when in its virgin condition and supports a dense growth of sedges and coarse grasses. Where it has been drained it proves very productive for general farm crops. Drainage is the first treatment which the soil needs and when this is accomplished crop growth may be quite satisfactory. Small applications of farm manure would be of benefit on drained areas to stimulate available plant food production. Applications of a phosphorus fertilizer would probably be of value.

LINDLEY FINE SAND (135)

The Lindley fine sand is a very minor type in the county covering only 0.2 percent of the total area. It occurs in several small areas in association with the Shelby soils and the other drift soils in the southwestern part of the county. The largest area and the only area of any size is southeast of Filmore. Other areas occur east of Cascade, northwest of Filmore along John creek and along the county line south of Worthington, southeast of Dyersville and in section 36 of Dodge township. Other very small areas occur scattered thru the drift upland.

The surface soil of the Lindley fine sand is a light brown or light grayish-brown loose fine sand. The texture changes very little to a depth of 3 feet. The color of the soil becomes a pale yellow gradually changing to a lighter color at the lower depths. The type is found on small knolls and low ridges and also at the base of slopes. Many of the areas are too small to separate and are included with the Shelby fine sandy loam.

The type is of little importance agriculturally. It is farmed with the Shelby soils. Its yields are somewhat lower. Treatments required are very much the same as those needed for the Shelby fine sandy loam. A liberal application of farm manure is particularly important. Leguminous crops should be used as green manures. The soil is acid and in need of lime, and it will undoubtedly respond to a phosphorus fertilizer.

LOESS SOILS

There are three loess types in the county and these with the steep phase of the Clinton silt loam and the light colored phase of the Tama silt loam make five loess areas. The soils are classified in the Clinton and Tama series and together they cover 71.4 percent of the total area of the county.

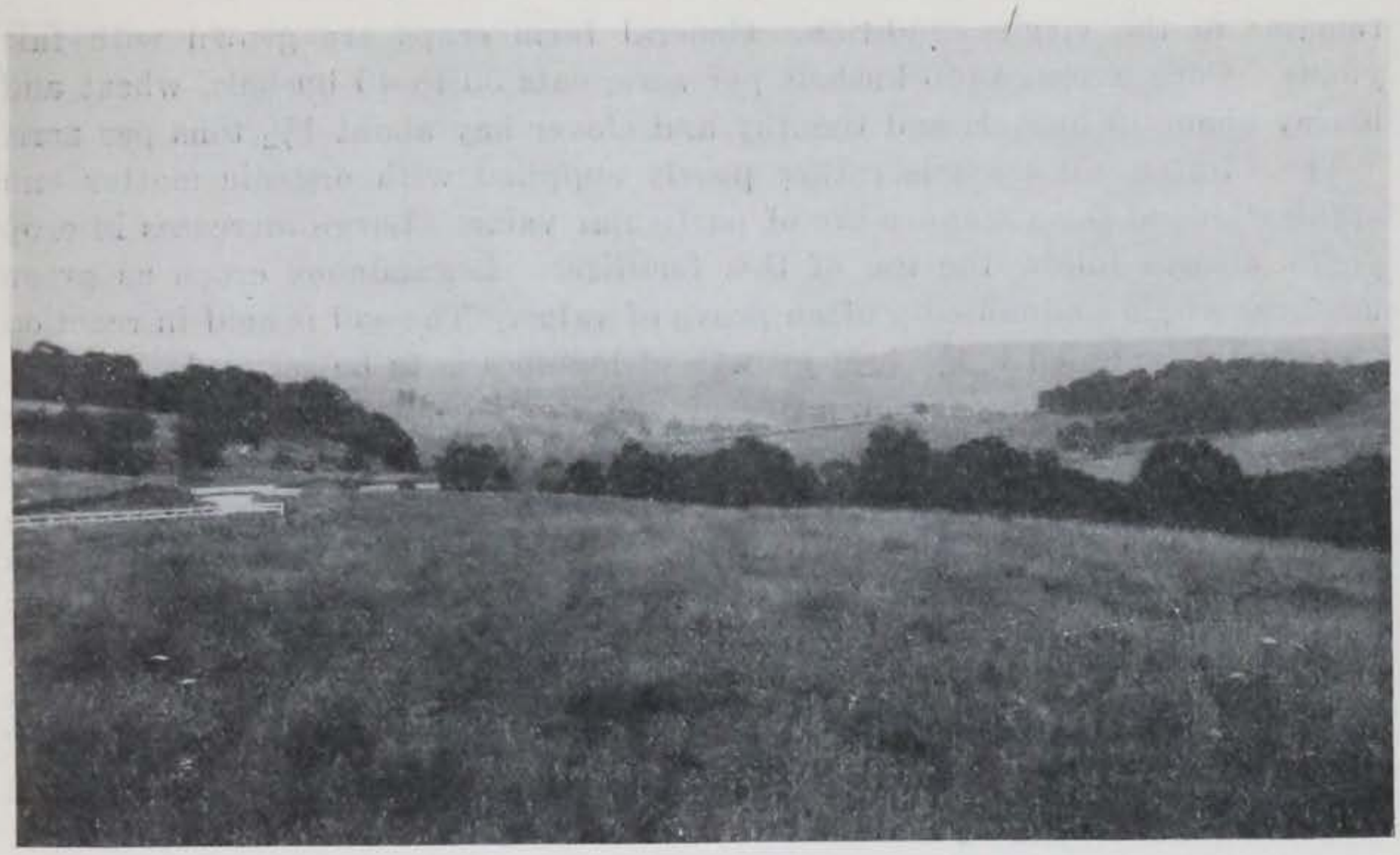

Fig. 9. Clinton silt loam topography.

CLINTON SILT LOAM (80)

The Clinton silt loam is the most extensive soil type in the county. Together with the steep phase which is very much smaller in extent it covers 50.4 percent of the total area. The typical soil covers 45.1 percent of the county. It occurs widely distributed over the uplands of the county being the chief upland soil thruout the eastern part of the county and thru the central portion. It is also an important upland type in the northwestern part of the county, and occurs in smaller areas in the southwestern part.

The surface soil of the Clinton silt loam is a grayish to light brown silt loam 4 to 8 inches in depth. Below this point there is frequently a layer of 2 to 6 inches of ash colored or very light gray silt. At depths of 12 to 15 inches the soil is a buff colored silty clay loam more compact than the upper layers. At 30 to 40 inches the subsoil is a friable silt loam grading into the grayish iron stained subsoil silt. The surface soil varies considerably in color and thickness being darker and thicker at the bases of slopes and in the shallow areas at the heads of drainageways. On the steeper areas where erosion has occurred the surface soil is thin and yellow spots occur showing the exposure of the lighter colored subsurface. In some areas, the surface soil is so light that it appears almost white when dry. This is true on nearly level land such as the flat tops of ridges just back of the cliffs along the Mississippi river. In many areas the light gray silty subsurface layer is very imperfectly developed and often it does not occur. All of these variations of the typical soil are minor in importance as the areas are too small to show on the map.

In topography the Clinton silt loam is rolling to hilly and some rather steep slopes are included. Drainage is quite adequate. The land on this type was originally covered with a growth of white oak, hickory, red oak and aspen. The greater part of the type is now cultivated and probably less than 5 percent

remains in the virgin condition. General farm crops are grown with fair yields. Corn averages 40 bushels per acre, oats 30 to 40 bushels, wheat and barley about 15 bushels and timothy and clover hay about 1½ tons per acre.

The Clinton silt loam is rather poorly supplied with organic matter and applications of farm manure are of particular value. Large increases in crop yields always follow the use of this fertilizer. Leguminous crops as green manures would undoubtedly often prove of value. The soil is acid in reaction and should be limed if the best growth of legumes is to be secured.

Phosphate fertilizers might prove of value and tests of acid phosphate or rock phosphate are urged. The experiments discussed earlier in this report show quite definitely the value of applications of manure and lime to this soil, and they indicate also the possibility of profitable effects from the use of a phosphate fertilizer. Hence it seems very desirable for farmers to determine by simple tests on their own soils whether or not a phosphate is needed and if so which particular phosphate fertilizer should be employed. The type is subject to erosion and care should be taken to prevent the washing away of the surface soil or the formation of gullies. Some method should be followed to prevent serious injury to the land from erosion.

CLINTON SILT LOAM (STEEP PHASE) (176)

The steep phase of the Clinton silt loam is small in area covering 5.3 percent of the total area of the county. It occurs chiefly thruout the central portion of the county in association with the typical Clinton and with the Dubuque silt loam and the Genesee silt loam on the bottoms. The areas are usually narrow and frequently separate the more gently rolling uplands from the bottoms. The Dubuque silt loam separates the typical Clinton from the steep phase, which in turn joins the Genesee silt loam on the bottoms. In other areas the steep phase joins the typical soil of the Dubuque silt loam on the upland. The largest areas of this phase are found along the Little Maquoketa river in Center township and to the north thru Iowa and Concord townships. Other important areas occur along Catfish creek and Gonger creek in Table Mound township and to the east thru Mosalem township.

The surface soil of this phase is practically the same as that of the typical soil and the soil conditions are very similar thruout this section. The phase is confined to slopes which are uniformly steep and deeply cut by streams. Some steep slopes which should really be included are too small to show separately on the map and are included in the typical soil. Small bodies of dark gray or slaty black silt loam and clay loam underlaid by stiff clay or shale rock at shallow depths are included with this soil. The areas are known as "spouty" land and really form a distinct soil type but could not be separated on the map because of their small extent.

The phase was originally forested with white oak, bur oak, hickory, elm and aspen and a small amount of the land is still in original forest growth. Probably 60 to 70 percent of the area as mapped is under cultivation, being utilized chiefly for corn, hay and oats.

The soil yields somewhat lower than the typical soil but the differences are not large. It is subject to erosion and gullying occurs to a considerable

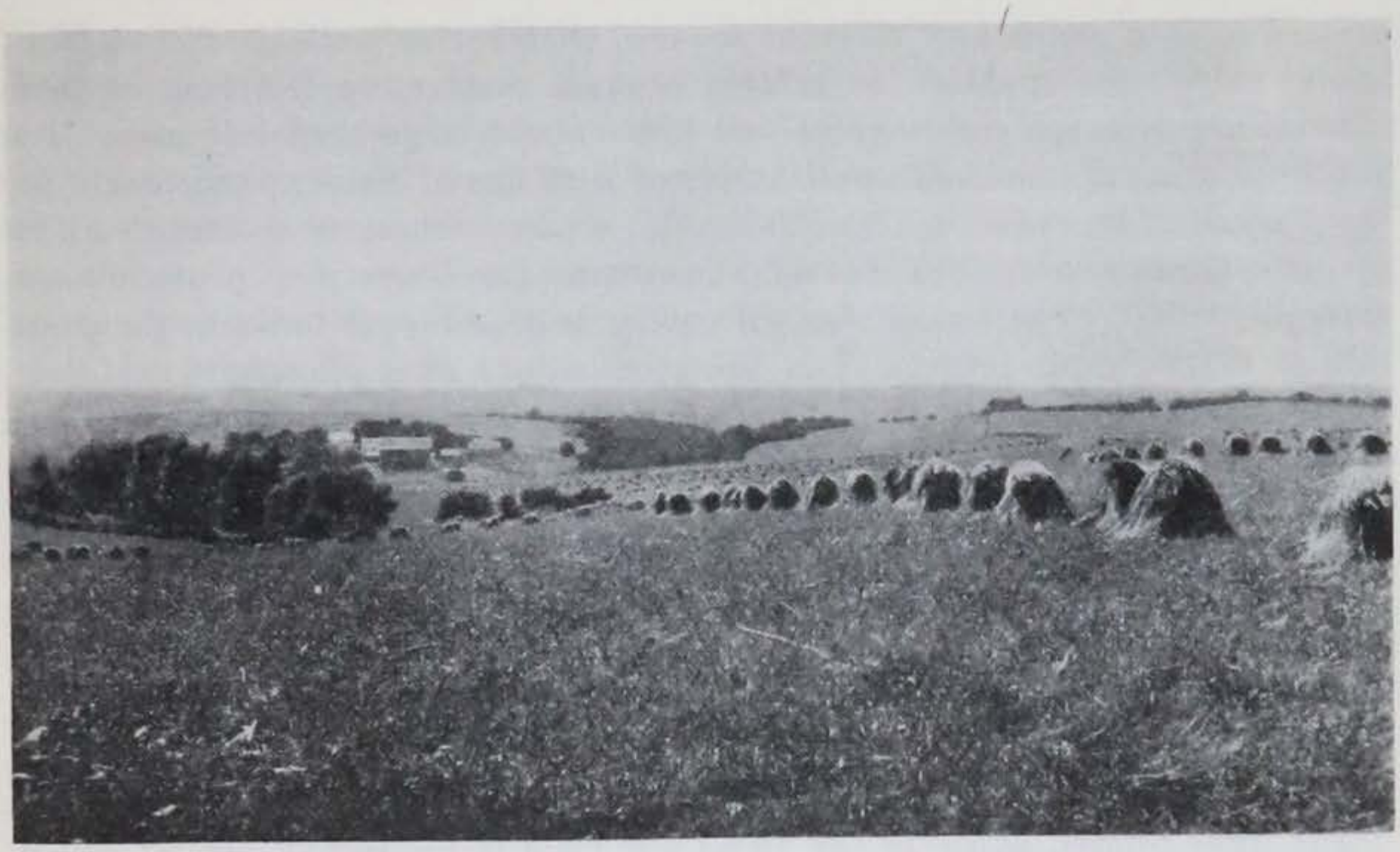

Fig. 10. Tama silt loam in Dubuque county.

extent. The chief treatment needed is protection from erosion and control of gullying. Other treatments necessary are similar to those required by the typical Clinton. Liberal amounts of farm manure are needed and leguminous crops should be used as green manure. The soil is acid and in need of lime and the application of a phosphorus fertilizer would undoubtedly prove of value. On some areas the steep phase should undoubtedly be kept in pasture as the most desirable method of utilizing the land.

TAMA SILT LOAM (120)

The Tama silt loam is the third largest soil type in the county. Together with the light colored phase which is somewhat larger in extent it covers the second largest area, 19.6 percent of the county. Alone it covers 7.9 percent of the county. It occurs mainly on the uplands in the southern and western parts of the county. The principal areas are in Dodge, Taylor, Vernon, Prairie Creek and Washington townships. Small areas occur in other parts of the county in the western and southern townships.

The surface soil of the Tama silt loam is a dark brown, mellow silt loam to a depth of 12 to 18 inches. Below this point the soil gradually changes to a lighter brown somewhat more compact silty clay loam. The dark color of the surface soil sometimes extends to a depth of 20 to 30 inches. In topography the type is gently rolling and the natural drainage is generally quite adequate. There are some areas where the type occurs in more level locations and drainage conditions are not quite adequate.

All of the type is under cultivation and the chief crops are corn, oats and timothy and clover hay. Average yields of corn amount to 45 bushels per acre, oats yield about 40 bushels and hay 1½ to 2 tons per acre.

The Tama silt loam is quite satisfactorily productive but considerable in-

creases in crop yields may often be secured thru better methods of soil treatment. Altho the type is not low in organic matter, applications of farm manure are of considerable value and bring about large crop increases. The soil is acid in reaction and applications of lime are of value, particularly for the growth of legumes such as alfalfa and clover. There is no large content of phosphorus and applications of phosphorus fertilizers may prove of considerable value. The tests discussed earlier in this report indicate the possibilities of profitable returns from the applications of a phosphate fertilizer, but it is not yet possible to say definitely that the use of a phosphate will always be of value. It is urged that farmers test the use of a phosphate on this soil and they may also compare the relative effects of acid phosphate and rock phosphate, determining which material will be the most profitable for use. By the liberal application of farm manure the use of lime as needed and possibly the application of a phosphate, larger crop yields may be secured on this type and it may be kept in a condition of permanent fertility.

TAMA SILT LOAM (LIGHT COLORED PHASE) (177)

The light colored phase of the Tama silt loam is the second largest soil in the county covering, with the typical soil, 19.6 percent of the total area, and alone 11.7 percent of the county. It occurs mainly in the central and western parts of the county in association with the Clinton and Carrington soils, the largest areas being found in Liberty, Concord, Iowa and Cascade townships. Considerable areas occur in the other western, central and southern townships.

The surface soil of the phase is somewhat lighter in color than the typical Tama. Otherwise the soil is very similar in general characteristics to the typical soil. The surface layer ranges from 15 to 30 inches in depth, averaging 18 to 20 inches. There are gradual changes from this phase to the typical soil and also to the Clinton silt loam and in many cases the boundary lines are rather arbitrary. In topography the phase is gently rolling or somewhat like the typical soil. The drainage is quite adequate and artificial drainage is rarely needed. The topography is not steep enough to lead to excessive erosion altho some surface washing does occur.

Probably most of the area in this phase was originally forested and in a few small areas there is still a growth of white oak and bur oak remaining. Practically all of the areas in the soil are now under cultivation and the yields are very much the same as on the typical Tama, averaging only slightly lower. The needs of the soil are very similar. It will respond to applications of farm manure, lime is needed to remedy acid conditions and applications of a phosphate fertilizer would probably prove of value.

CLINTON VERY FINE SANDY LOAM (178)

The Clinton very fine sandy loam is a minor type in the county covering only 1.4 percent of the total area. It occurs in several separate bodies in Cascade, Dodge, Taylor, White Water, and Prairie Creek townships. The largest areas are found in White Water townships north of Fillmore, in Prairie Creek township west of Washington Mills and in Taylor township northwest of Epworth.

The surface soil of the Clinton very fine sandy loam is a grayish and light brown very fine sandy loam 10 to 15 inches in depth, underlaid by a buff colored more compact very fine sandy clay loam. This material becomes less clayey at depths of 30 to 40 inches and at 4 to 5 feet grades into a grayish and yellowish loose mixture of very fine sand and silt. The surface soil varies somewhat in color and in depth in different areas depending upon the topography location. The topography varies from rolling or moderately hilly to rather steep.

The land where this soil occurs was originally forested, the growth consisting mainly of bur oak, red oak, white oak, hickory and aspen. Most of the land is now cleared and under cultivation, and general farm crops such as corn, oats and hay are grown. Yields on this type are much the same as those secured on the Clinton silt loam averaging perhaps slightly less.

The soil is somewhat drouthy and crops are apt to suffer in dry seasons. The chief need of the soil is for liberal additions of farm manure or the turning under of leguminous crops as green manures in order to build up the organic matter supply. When this is accomplished there is less danger of injury to crops in dry seasons and the soil is made more productive. Applications of lime are necessary especially for the growth of legumes and phosphate fertilizers would undoubtedly give profitable effects. Tests of acid phosphate on this type are desirable.

TERRACE SOILS

There are four terrace types in the county classified in the Judson, O'Neill and Davenport series. They are all small in area together covering only 1.2 percent of the county.

JUDSON LOAMY SAND (179)

The Judson loamy sand is the largest of the terrace soils covering, however, only 0.5 percent of the total area. It occurs mainly along the Mississippi river in two rather extensive areas, one at the mouth of the Little Maquoketa river and the other north of the city of Dubuque and in several smaller areas. Small areas are also found along John creek in White Water township and in the vicinity of Cascade and Worthington.

The Judson loamy sand is brown in color to a depth of 20 to 30 inches below which point the sand is yellowish in color. The loamy sand texture usually continues for depths of 3 to 4 feet changing to a coarse sand at depths from 3 to 15 feet. There are some variations in the soil in different areas, the depth to which the brown color extends being somewhat variable and there being some variation in texture. In some places there is a layer of clayey sand within 3 or 4 feet of the surface. In a part of the area at the mouth of the Little Maquoketa river east of Dyersville the soil is a dark brown coarse sand and fine gravel, containing, however sufficient finer particles to produce a somewhat loamy structure. The subsoil is a mixture of sand and gravel. The soil in this area is quite drouthy but in normal seasons general farm crops and garden vegetables, melons and small fruits do well. In topography the Judson loamy sand is level or only slightly uneven and hummocky. It is nearly always dry and crops are apt to suffer in dry seasons for lack of moisture.

Fig. 11. O'Neill loam along North Fork Maquoketa river.

Most of the type except that within the city of Dubuque is utilized for general farm crops, for the growing of truck crops and small fruits. The soil is well suited for early vegetables and good yields are secured with proper treatment and moisture conditions. Average yields of corn, oats and hay are lower than on the silty soils of the uplands or on the lower-lying bottomlands. This type is particularly in need of organic matter to make it more productive and it should receive liberal applications of farm manure. Leguminous crops should be turned under as green manures in many cases in order to increase the organic matter content of the soil. The improvement of the soil from the standpoint of organic matter will mean that it will be less apt to be drouthy. The type is acid and lime should be employed. Applications of phosphorus fertilizers would undoubtedly prove of value and where truck crop or vegetables are grown applications of complete commercial fertilizers especially designed for garden crops may be profitably employed.

O'NEILL LOAM (108)

The O'Neill loam is a minor type in the county covering 0.4 percent of the total area. It occurs only in the western part of the county and chiefly in the vicinity of Dyersville and Worthington. There are no large areas, the most extensive being found just southeast of Dyersville. Small areas occur along the North Fork Maquoketa river in the southwestern part of the county.

The surface soil of the O'Neill loam is a dark grayish-brown or dark brown loam varying in depth from 8 to 12 inches. The upper subsoil is a lighter brown rather coarse loam underlaid at depths from 18 to 30 inches by a loose porous coarse sand and gravel. There are variations in the soil in different localities and some places the sand is rather coarse. In some of the flatter areas, the upper subsoil contains larger amounts of silt and even silty layers between the beds of coarse material. The type is found on low terraces only

a few feet above the present flooding area. The drainage is good to excessive. The loose open nature of the subsoil makes the land drouthy and in dry seasons the crops may suffer.

Most of the type is under cultivation and corn and grasses are the principal crops grown. Average yields are secured in favorable seasons but large increases in crop yields may be secured thru the liberal application of farm manure, the use of leguminous crops as green manures, the application of lime, which is needed, and possibly also by the use of acid phosphate.

JUDSON SILT LOAM (131)

The Judson silt loam is a minor type in the county covering only 0.2 percent of the total area. Only a few small areas of this type have been mapped, one at the mouth of Catfish creek, another east of Sageville, three along the North Fork Maquoketa river, two along White Water creek and two along the river north of Dyersville. One of these latter areas is the most extensive occurrence of the type in the county.

The surface soil of the Judson silt loam is a brownish silt loam mellow or loamy in structure extending to a depth of 10 to 20 inches. Below that point the soil is a yellowish or buff colored silt. There is little variation in texture thru the 3 foot section and the color gradually becomes lighter at the lower depths. Sometimes the subsurface soil is somewhat more compact and clayey than the surface soil.

The type is used for general farm crops and the yields are much the same as on the Clinton silt loam. Improvement in crop production may be brought about thru the liberal application of farm manure or the turning under of leguminous crops as green manures. The type is acid and should be limed for the best growth of legumes. Applications of phosphorus fertilizers would undoubtedly prove of value.

DAVENPORT CLAY LOAM (180)

The Davenport clay loam is a minor type in the county covering only 0.1 percent of the total area. It is found only in one area in the county in the vicinity of Sageville, occupying an acreage of about 250 acres.

The surface soil of the Davenport clay loam is a dark gray compact somewhat plastic silty clay loam, extending to a depth of 3 to 6 inches. At that point it changes to a fine grained, stiff, somewhat impervious clay to a depth of 3 feet or more. The subsoil clay is grayish, yellowish and chocolate colored and generally calcareous. The type occurs on the terraces 40 to 50 feet above the first bottoms. Drainage is poor on account of the impervious clay subsurface.

The land is not regularly used for cultivated crops altho in some areas good yields of general farm crops have been secured. The type should be well drained and should receive applications of farm manure in order to put it in good condition for crop growth. Applications of phosphorus fertilizers might prove of value and tests are very desirable.

SWAMP AND BOTTOMLAND SOILS

There are five swamp and bottomland soils in the county classified in the Genesee and Wabash series, and there is also an area of riverwash. The total area in swamp and bottomland soils amounts to 9.9 percent of the county.

GENESEE SILT LOAM (71)

The Genesee silt loam is the most extensive bottomland type, covering 4.2 percent of the county. It occurs in numerous areas thruout the county, along the various streams. The areas are all narrow strips seldom more than ¼ of a mile in width and in many places less than 100 yards wide.

The surface soil of the Genesee silt loam is a light brown and very dark gray silt loam and loam, extending to depths of 20 to 40 inches. The subsoil is a clay loam or clay similar in color to the surface soil. The soil is variable, as is usually the case with bottomlands and sometimes a stiff clay layer occurs or layers of sand and gravel. The color variation is sometimes considerable frequently the darkest color appearing at 20 to 36 inches. There has been some exaggeration in the mapping of the narrow strip of soil separating the bottom from the adjacent upland and this strip is somewhat different from the typical Genesee. These narrow strips consist of a light brown to dark brown silty loam underlaid at 20 to 36 inches by a grayish, bluish-black silty clay loam. There is usually a high content of organic matter to a depth of 3 feet and the soil is often wet and in need of drainage. These areas could not be separated from the bottomland because of their small extent. The Genesee silt loam lies 3 to 8 feet above the beds of the streams and is subject to overflow.

Most of the land is uncultivated and utilized for pasture. This is due to the fact that the bottomlands are narrow and the streams are winding, which makes the land difficult to cultivate. When it is utilized for general farm crops good yields are secured in favorable seasons, particularly of corn. There is always the danger of injury from overflow. The type is poorly drained in some spots and if crops are to be grown more adequate drainage should be provided. When cropped the land will respond to small applications of farm manure, the application of lime to remedy acidity and possibly the application of a phosphorus fertilizer.

WABASH SILT LOAM (26)

The Wabash silt loam is the second largest bottomland soil, covering 2.1 percent of the county. It occurs along the rivers and creeks in the western and central southern parts of the county, being found generally along White Water creek and the North Fork Maquoketa river. It occurs in narrow strips along the streams the width of the bottoms being very much the same as those in the eastern part of the county where the Genesee silt loam occurs.

The surface soil of the Wabash silt loam is a mellow silt loam, dark brown to almost black in color. It grades gradually into a dark brown, dark gray or mottled brown and gray heavy clay loam. There are some variations in the type as may be expected, and in some areas the soil is lighter in color and varies somewhat in texture. In the areas, where the streams flow thru Clinton upland, there is a light colored silt loam covering over the typical

Wabash. In other cases there are deposits of material from the upland laid down over the Wabash on the bottoms.

The greater part of the Wabash silt loam is under cultivation and corn is the chief crop grown. Hay and small grains are produced to some extent and occasionally other crops are grown. The type is quite productive in favorable seasons but is apt to need drainage. It is subject to overflow, and crops may be injured in some seasons. Small applications of farm manure would be of value when the soil is to be used for farm crops. It is acid and lime should be applied and it might also respond to applications of phosphorus fertilizer.

WABASH STONY SILT LOAM (COLLUVIAL PHASE) (181)

The Wabash stony silt loam, colluvial phase, is a minor type in the county, covering 1.6 percent of the total area. It occurs along the bluffs bordering the Mississippi river and along the lower courses of the Little Maquoketa. There are small areas along some of the other larger streams of the county. The areas are all narrow and of little agricultural value.

The surface soil is mainly a dark brown silt loam and loam containing rock fragments, stones and gravel. The subsoil is a yellowish-brown clay loam and clay. The upper slopes consist of out-crops of lime rock on which there are scattered patches of soil probably loessial. In general the thin covering of loess has been washed down the slopes. The land consists mainly of precipitous rock bluffs and is valued chiefly for its forest growth. It has small value for pasturage. There is a dense growth of white oak, red oak, walnut, hickory, elm, hard maple, bass wood, and aspen on the slopes. Small patches of soil at the bases of the bluffs might be used for growing fruits or for garden crops.

GENESEE SILTY CLAY LOAM (182)

The Genesee silty clay loam is a minor type in the county covering 1.2 percent of the total area. It occurs on the bottoms along the lower courses of the Little Maquoketa river and Catfish creek, and most of the low lying bottomlands along the Mississippi river. The largest areas are found east of Sageville, east of Dubuque and east of Massey on Green Island. Rather considerable areas occur along the Little Maquoketa river south and west of Sageville.

The surface soil of the type is a gray and light brown compact silt loam grading at depths of 2 to 4 feet into a slightly more compact clay loam and silty clay. At shallow depths there is a lead gray color specked with brownish and blackish iron stains. There are some small areas of the silt loam included with the type as they could not be separated. The boundary lines separating this soil from the Genesee silt loam are frequently rather arbitrary as there is apt to be a gradual transition from one type to the other. The type lies 6 to 10 feet above the level of the streams and is subject to overflow. It is very poorly drained naturally and when cultivated is in need of artificial drainage.

The higher land on the islands in the Mississippi river is heavily forested with soft maple, ash, and elm, and the lower areas are covered with a willow growth. Very little of the land has been cleared and used for cultivation because of the frequency of overflows. On cultivated areas corn is the chief

crop and in favorable seasons yields of 50 to 60 bushels per acre are obtained. Heavy crops of hay are also secured in good seasons. When cultivated the soil needs first of all to be thoroly drained, it would respond to small applications of farm manure and it should be limed.

RIVERWASH (53)

There is a small area of riverwash in the county, covering 0.4 percent of the total area. There are numerous small areas of this material along the Mississippi river and it consists of a variable material laid down by the river in recent deposits. It is found along the shores of the river and consists of loose sand on alternating layers of grayish silt and sand. Some of the areas are permanently wet and all are subject to overflow. It supports a growth of willows and some cotton and soft maple. The land has practically no agricultural value. Some of the bottomland within the city of Dubuque has been filled in with soil from excavations and refuse and the material is therefore extremely variable.

GENESEE FINE SANDY LOAM (117)

The Genesee fine sandy loam is a minor type in the county covering 0.4 percent of the total area. It occurs in very narrow strips along the streams in the southwestern part of the county, being found mainly along John creek and the North Fork Maquoketa river.

The surface soil of the Genesee fine sandy loam is a light brown friable fine sandy loam to depths of 20 to 30 inches. Below that point the material is somewhat lighter in color and contains a higher amount of clay. The surface soil varies from a sandy loam to a very fine sandy loam. These variations are included owing to their small extent.

Very little of the land is cultivated as the bottoms are narrow and the soil is subject to overflow. Blue grass and white clover support good pasturage. If cultivated the soil would be improved by additions of farm manure, the use of lime, the turning under of leguminous green manure and possibly by the application of a phosphorus fertilizer.

RESIDUAL SOILS

There are two residual soils in the county classified in the Dubuque and Gasconade series. Together they cover 7.9 percent of the total area.

DUBUQUE SILT LOAM (183)

The Dubuque silt loam is the larger of the residual soils and it is the third largest soil type in the county. It covers 7.6 percent of the total area. It occurs thruout the eastern and central portions of the county and to some extent in the south central part of the county. It occurs on the steep slopes and bluffs along the various streams and drainageways and also in narrow strips separating the Clinton silt loam from the steep phase. In some places it is found adjacent to the bottomlands. The type occurs, in general, in narrow ribbon-like strips altho there is a rather more extensive occurrence in Mosalem township.

The surface soil of the Dubuque silt loam is a grayish-brown or light brown mellow silt loam, grading into a yellow silty clay loam which at 20 to 36 inches

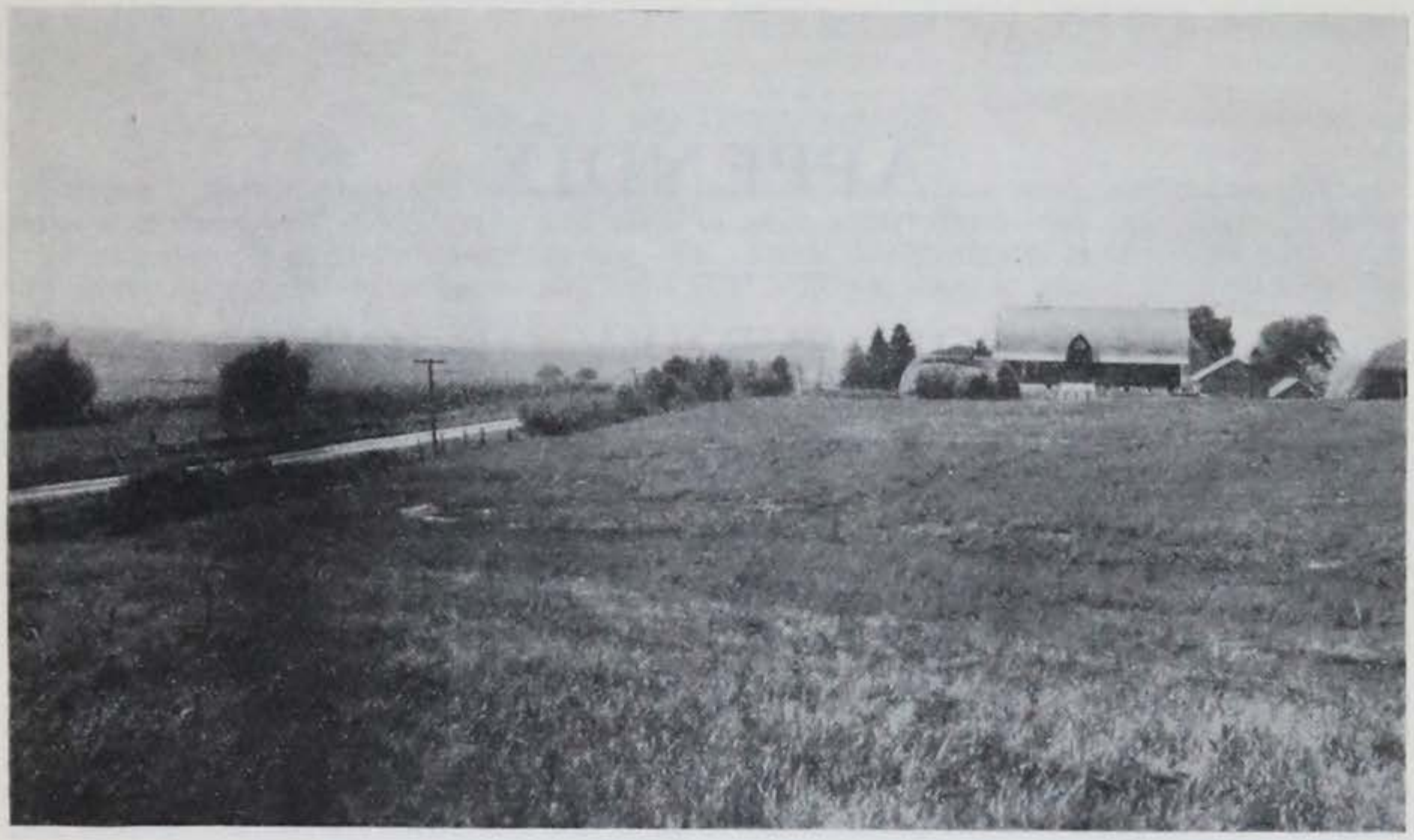

Fig. 12. Gasconade loam in foreground. Carrington loam background.

becomes a yellow or reddish rather stiff gravelly clay resting on limestone. Variation in the thickness of the soil and in the color are common. The soil on the tops of bluffs is generally lighter in color and the underlying clay is steeper and more reddish. At the base of the slopes the soil is somewhat darker in color and more loamy and open. These variations from the typical soil cannot be shown on the map owing to their occurrence in narrow strips. The subsoil is calcareous and frequently lime fragments occur in the surface.

All of the type was originally forested with white oak, red oak, walnut, elm and hickory. Partly cleared land provides excellent pasturage and blue grass grows well. The unfavorable topography makes little of the land suitable for cultivation. Only in small areas would it be desirable to grow cultivated crops. In general it should be kept in pasture. When cultivated the soil should receive applications of farm manure in order to bring about the best crop yields.

GASCONADE LOAM (184)

The Gasconade loam is a minor type in the county covering only 0.3 percent of the total area. It occurs in ridges, slopes and knolls chiefly in the western and southwestern parts of the county. The areas are all small and of minor importance. The largest occurrence of the type is along the county line south of Bernard. Other areas of importance occur in the vicinity of Dyersville. Numerous small areas are found scattered thru the southwestern townships.

The surface soil of the Gasconade loam is a brown to dark brown loam and sandy loam, underlaid by a thin layer of clay or clay loam and resting on limestone rock at shallow depths. In some areas there is only 3 to 6 inches of dark surface soil resting directly on rock. In other areas there is a shallow layer of stiff reddish clay separating the soil from the rock. In general the soil is a mixture of residual material formed from the weathering of the limestone with mineral particles derived from the drift and loess.

The areas of the type are from 2 to 40 acres in extent and much of it is so thin and stony that it cannot be plowed and therefore utilized only for pasture. Cultivated crops suffer for lack of moisture and pasture grasses are also apt to be injured by lack of water. The deeper variations of the soil are cultivated and frequently good yields of general farm crops are secured. When cultivated the soil should receive liberal applications of farm manure in order to bring about the best crop growth. It might also respond to applications of phosphorus fertilizers.

APPENDIX

THE SOIL SURVEY OF IOWA

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

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

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

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

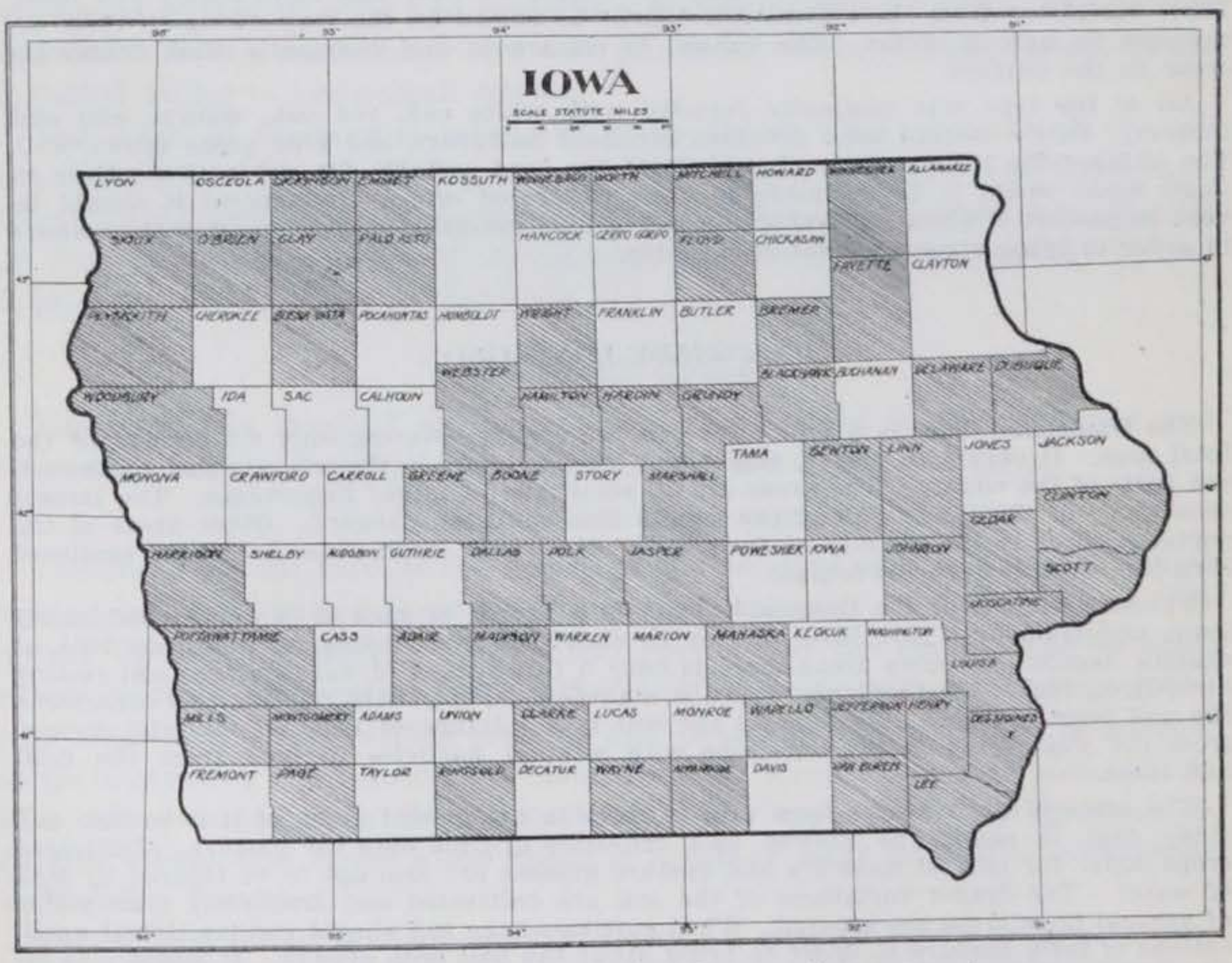

Fig. 11. Map of Iowa showing the counties surveyed.

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

PLANT FOOD IN SOILS

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

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the 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 frequestly 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

TABLE I. PLANT FOOD IN CROPS AND VALUE

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

Crop	Yield	Plant food, lbs.			Value of plant food			Total value of plant food
		Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	
Corn, grain.....	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 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
Barley, 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

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.

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 elemments 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 elements in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

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

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

REMOVAL FROM IOWA SOILS

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

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

PERMANENT FERTILITY IN IOWA SOILS

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

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be

delayed until the crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on other elements likely to be limiting factors in crop production.

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

CULTIVATION AND DRAINAGE

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

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

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during the periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily 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.

MANURING

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

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

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

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

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is possible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not

all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years.

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 the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exceptions to the general rule, as was shown by the tests of many representative soils reported in Bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

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

SOIL AREAS IN IOWA

There are five large soil divisions in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 12.

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

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

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

THE SOIL SURVEY BY COUNTIES

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

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much

greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

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

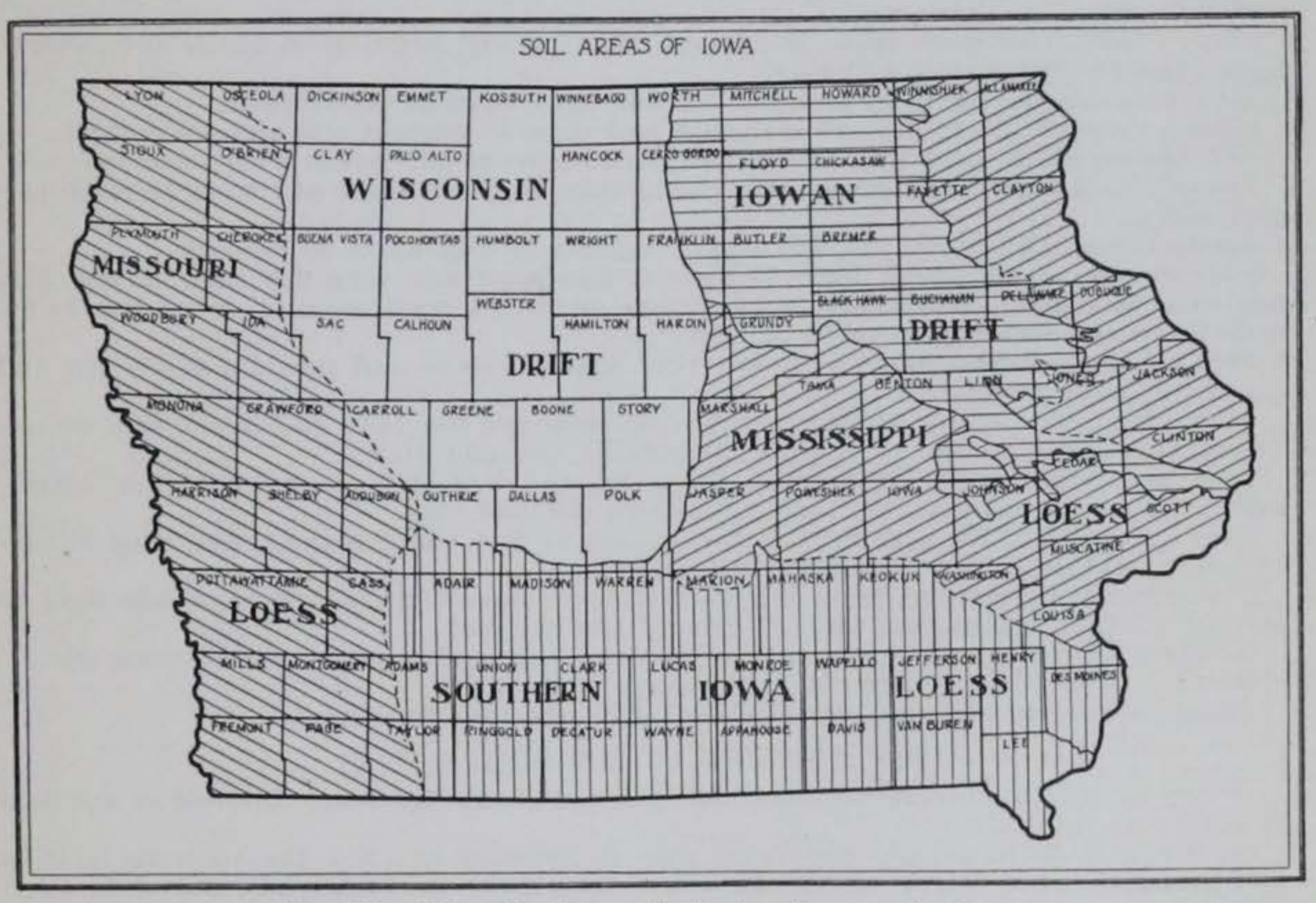

Fig. 12. Map showing principal soil areas in Iowa.

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 percent or more of organic matter, sometimes mixed with more or less sand or soil.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Gravels—More than 50 percent very coarse sand.

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

METHODS USED IN THE SOIL SURVEY

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

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

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

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by placing, 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 completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.

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

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